CUNNINGHAMIA

Volume 2(3) • 1991

ROYAL BOTANIC GARDENS SYDNEY
National Herbarium of New South Wales

Cunninghamia is published by the National Herbarium of New South Wales, Royal Botanic Gardens Sydney. It covers all aspects of plant ecology, in particular vegetation surveys and mapping, and plant community dynamics. It deals primarily with New South Wales.

Cunninghamia is published annually in July.

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Cover illustration
Black Box, *Eucalyptus largiflorens*, typical of floodplains and dry lake margins in south-west New South Wales.
Photo: Surrey Jacobs.

CUNNINGHAMIA

A journal of plant ecology

Volume 2(3) • 1991

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ISSN 0727–9620

National Herbarium of New South Wales
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The effect of 200 years of European settlement on the vegetation and flora of New South Wales

John Benson

Abstract

Benson, J.[*] *(New South Wales National Parks and Wildlife Service, P.O. Box 1967, Hurstville, NSW, Australia 2220) 1991. The effect of 200 years of European settlement on the vegetation and flora of New South Wales.* Cunninghamia *2(3): 343-370.* The vegetation of New South Wales is dominated by *Eucalyptus* (and other Myrtaceous genera) and *Acacia* and reflects adaptations to climatic change during the late Tertiary and Quaternary and to 38–45,000 years or more of Aboriginal burning. Of the ca. 6000 vascular plants in NSW, 1198 are alien and naturalised originating from Europe, Asia, the Americas, South Africa and the Mediterranean. At least 532 native species are rare or threatened. The native flora has been previously tentatively classified into 432 associations in 18 major community groups. Grazing and cropping have been the major causes of decline in the distribution and abundance of these associations and of rare or threatened species, but additional factors are urban expansion, forestry and invading weeds. Examples are *Rutidosis leptorhynchoides*, an endangered plant threatened by grazing and urban expansion, the recently cleared *Acacia harpophylla* forests, and coastal vegetation threatened by the invasive weed *Chrysanthemoides monilifera*.

Of the total area of NSW, 4.86% is reserved for conservation as of 1990; an estimated 42 per cent of plant associations and 49 per cent of rare or threatened species are adequately conserved as of 1990. Further survey and reservation is needed, particularly in tall open forests, wetlands, semi-arid and agricultural lands. Further research is required into endangered species, their habitats and the processes causing decline in populations.

Introduction

While Dutch and English sailors landed on the western and northern shores of Australia in the 17th century, it was Captain James Cook's voyage in 1770 that led to the first European settlement of Australia in 1788 on the east coast, where the city of Sydney now stands.

In the ensuing 200 years of European settlement of Australia, much of the vegetation has been greatly altered in abundance and distribution. Species have become extinct due to the activities of man, alien plants have been introduced, many becoming weeds in competition with native species, and some ecosystems are under severe threat because of over-exploitation. Adamson and Fox (1982) go so far as to suggest that no other continent has experienced such a rapid change.

Wells et al. (1984) estimate that forests, woodlands and tall shrubs covered 77-88% of New South Wales in 1788. Over half of this vegetation has been cleared, primarily for agriculture (Department of Arts, Heritage and Environment 1986, Reed 1990); During the first 130 years of European settlement 35.3 million hectares (44% of New South Wales) were ring-barked or partially cleared (Reed 1990). Furthermore, during a five year period in the 1980s, at least 2.2 million hectares were cleared. This represents a rate of 1183 hectares/day (Reed 1990). Land-clearing continues today in most parts of the State with indifference to contemporary views about the causes of land degradation, for example, the views expressed in the Murray-Darling Basin Natural Resources Management Strategy (Murray-Darling Basin Ministerial Council 1989).

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Pre-European history of the vegetation of south-east Australia

The history of Australia's vegetation is well documented by Beadle (1981), Barlow (1981), Groves (1981), Smith (1982) and White (1986). It is briefly discussed here to establish the environmental factors and previous human impact that have affected the vegetation.

After long periods of relative stability of climate and vegetation formations over most of the Tertiary, climate became more unstable in the Pliocene-Pleistocene epochs (Singh 1982). Rainforests covered much of Australia in the mid-Tertiary but retracted with the onset of cooler and drier climatic trends. Pollen diagrams from Lake George in south-east New South Wales (Singh, Kershaw & Clark 1981), and Lynch's Crater in north-east Queensland (Kershaw 1978) detail changes in vegetation during the latter parts of the Pleistocene. These changes principally comprise oscillations between rainforest plants and dry sclerophyll plants.

A tentative reconstruction, based on somewhat limited data, is given by Ross (1984) who describes the major environmental changes in south-east Australia over the late Quaternary. By about 32,000 years ago south-east Australia experienced interstadial conditions that were cooler and wetter than today. Rainforests had retreated to refugia and grasslands dominated high country and semi-arid regions of the continent. During the last ice age between about 25,000 and 12,000 years ago the vegetation adapted to dry, cool conditions. Grasslands were common and forests became more sparse in their structure. When the ice age ended the treeline rose and forests once again expanded, with *Casuarina* invading many areas. Rainforest also expanded from its refugia (Webb & Tracey 1982). This corresponded with a relatively wet period up to 5000 years ago. During a slightly drier period between 3000 and 1000 years ago some areas reverted to more grass-dominated vegetation (Ross 1984). The present-day slightly less xeric vegetation types were established during the last 1000–1500 years (Ross 1984).

The impacts of Aborigines on Australian vegetation

It is difficult to specify the effect of 45,000 (Nanson, Young & Stockton 1987) to 60,000 (Wright 1986) years of Aboriginal practices on Australia's vegetation because they occupied the continent simultaneously with great changes in climate.

The most significant way in which Aborigines may have altered their environment would have been through the use of fire. The reasons attributed to Aborigines using fire include: flushing game (Barrallier 1802, Hunter 1793); to stimulate seed production of edible plants, for example cycads (Beaton 1982); to stimulate the growth of young shoots, thereby increasing the amount of food for game in an area (Lewis 1982); easing travel through the countryside; signalling; and frightening enemies.

Over the last few decades there has been a good deal of debate over the extent of change to the Australian vegetation caused by Aboriginal burning. Tindale (1959) followed by Jones (1969) suggests that Aborigines had radically altered the environment through their use of fire. Alternatively, Horton (1982) postulates that Aborigines were conservative when using fire and merely maintained natural fire patterns in vegetation.

Bowman and Brown (1986) reject Horton's model of fire-vegetation relations by citing data that support the view that frequent burning favours plants adapted to fire and increases the probability of fire. They maintain that Aborigines were capable of burning mature forests in regions of low fire frequency thus causing changes to the vegetation e.g. from *Nothofagus* forests to sedgelands. However, the survival of the fire-sensitive pencil pine *Arthrotaxis cupressoides* during Aboriginal occupation in the Alpine zone of Tasmania, and its subsequent decline due to European firing, indicates that Aborigines used fire differently from Europeans or did not occupy and burn all regions (Bowman & Brown 1986).

Although evidence is lacking, it is likely that some plant species are now threatened because they were favoured by Aboriginal burning regimes which are now absent. Examples include species of *Swainsona* (Fabaceae) (Parsons & Browne 1983). Conversely, some species may have become rare primarily due to Aboriginal burning.

A general agreement beginning to emerge about the level of Aboriginal impact on Australian vegetation through their use of fire (Clark 1983, Bowman & Brown 1986), lies somewhere between the views of Horton (1982) and Jones (1969). Clark (1983) concludes that 'it is likely that Aborigines played a maintenance role to the major determinant of vegetation, climate'. There are certainly numerous records in the journals of early European explorers such as Mitchell in New South Wales (1848) and Robinson in Tasmania (1829–1834) describing the common Aboriginal practice of firing the vegetation but it is difficult to weigh the relative importance of Aboriginal use of fire against climatic change. Also, we do not have enough knowledge of the differences in Aboriginal use of fire between different groups and in different parts of Australia. Whatever the causes, the vegetation that was present in most regions when Europeans arrived was well adapted to fire (Gill 1975).

The present vegetation of New South Wales

New South Wales contains a range of plant associations as a consequence of steep north-south and east-west environmental gradients. This diversity in associations is reflected in the richness of plant species (Table 1).

Table 1. Number of vascular plant species in New South Wales (from Jacobs & Pickard 1981)

Plant group	No. native species	No. naturalised species (%)	Total
Pteridophyta	199	5 (3)	204
Gymnosperms	25	3 (11)	28
Angiosperms (monocots)	1171	314 (21)	1485
Angiosperms (dicots)	3569	876 (20)	4445
Total	**4964**	**1198 (19)**	**6162**

The majority of the plant associations present today are dominated by *Eucalyptus* or other trees and shrubs in the Myrtaceae, or *Acacia* in the Fabaceae. Exceptions are alpine and rainforest plant associations and chenopod shrublands of the interior. With the exception of rainforest flora, most of the flora in New South Wales displays xeromorphic characteristics. Xeromorphism has evolved as an adaptation to infertile soils and/or lack of water (Beadle 1981). Many xeromorphic genera and species have evolved from rainforest species (Andrews 1916, cited in Beadle 1981; Webb & Tracey 1982). Proteaceae has rainforest genera such as *Stenocarpus*, *Orites*, and *Macadamia* but also xeromorphic genera such as *Hakea*, *Grevillea* and *Banksia*.

The distribution of plant species in New South Wales is skewed towards the eastern, moister and more complex (in terms of substrates and topography) botanical divisions of the State. The drier western plains that cover more than half of the state contain far fewer plant species than do the eastern ranges and coast. Cunningham et al. (1981) list approximately 2000 taxa of plants occurring in western New South Wales, yet a comparable number of plant taxa are present within the Sydney region on the east coast (Beadle, Evans & Carolin 1982).

Localised endemism is also more common in the eastern parts of New South Wales where varied geologies, greater variation in local climate and isolated tablelands or mountains have favoured the evolution of distinctive floras. Such areas include: the alpine zone of Kosciusko National Park on the Southern Tablelands with 21 endemic species of vascular plants (Costin et al. 1979); the southern escarpment overlooking the Jamieson Valley in the Blue Mountains (Keith & Benson 1988); outlying mountains on the South Coast and the Northern Tablelands; and the subtropical rainforest remnants of the 'Big Scrub' area on the far North Coast.

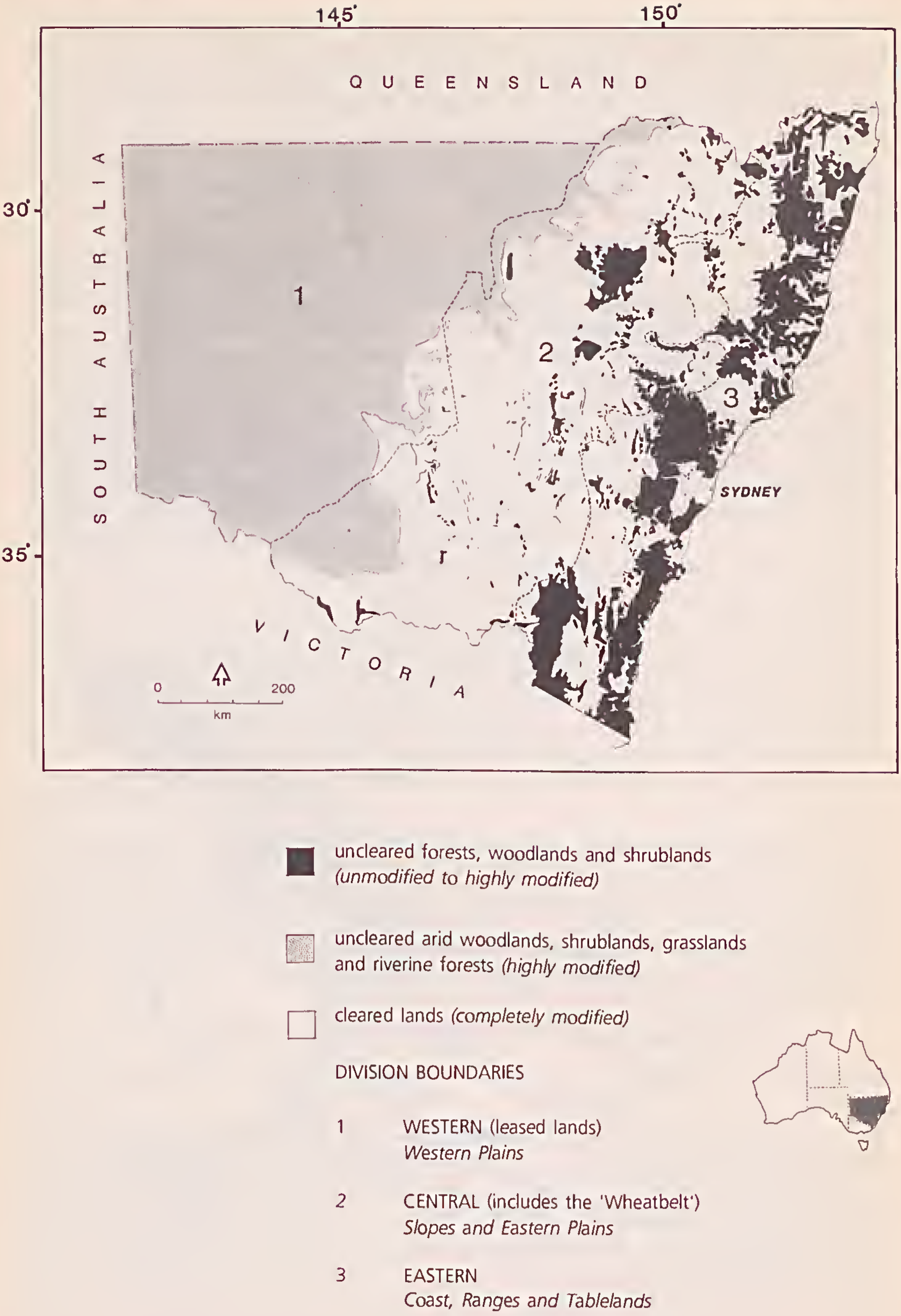
Beadle (1981) erected a floristic classification for Australia's vegetation. This has been refined by Benson (1989) for New South Wales, in which 432 plant associations are listed. These associations are allocated to 18 vegetation groups (based on the Beadle 1981 classification) reflecting the major biogeographic provinces of the State. This classification is currently being revised (Hager & Benson 1990; Robinson & Benson 1990).

Effect of European settlement on the vegetation of New South Wales

Most of New South Wales has either been moderately or highly modified by humans since European settlement 200 years ago (Adamson & Fox (1982), Leigh et al. (1984), (Figure 1). The regions that have been most markedly altered (besides urban centres) are those that contain better soils on flat to undulating topography. They include the coastal alluvial valleys and plains, basalt plateaux, the less steeply sloping tablelands and the Central Division of the State incorporating the Western Slopes and eastern parts of the Western Plains.

At the time of European settlement rainforest covered about 1% of New South Wales, but because it occupied rich soils, some of the largest expanses (for example the Big Scrub and on the Illawarra) were cleared by the mid 19th century (Frith 1977; Strom 1977). Today, only about one quarter of the original rainforest (192,000 hectares) remains structurally intact (Floyd 1990). The largest remaining stands are now protected in reserves and are registered on the World Heritage List.

Very little of the various associations of tall moist forest occurring on higher nutrient soils on the eastern tablelands and coast remain undisturbed. Initially clearing for settlement and agriculture eliminated much of this habitat from the coastal valleys and flatter parts of the tablelands. With the exception of some relatively small stands



■ uncleared forests, woodlands and shrublands *(unmodified to highly modified)*

▨ uncleared arid woodlands, shrublands, grasslands and riverine forests *(highly modified)*

☐ cleared lands *(completely modified)*

DIVISION BOUNDARIES

1	WESTERN (leased lands) *Western Plains*
2	CENTRAL (includes the 'Wheatbelt') *Slopes and Eastern Plains*
3	EASTERN *Coast, Ranges and Tablelands*

Figure 1. Modification of the native vegetation of New South Wales since European settlement in 1778.

in conservation reserves, most of the remaining tall forest has been or is presently being logged and subject to changed fire regimes, including frequent control burning. This has significantly changed the age/size structure of these forests and the composition of the understorey. Regenerating forests on both public and private land are coming under increasing pressure for exploitation as timber resources run low and alternative uses of timber are being proposed for supplying woodchip exports, pulp mills and export firewood (NSW Department of State Development 1989; National Parks and Wildlife Service of NSW 1990).

Even in areas where woodlands or forest were left uncleared, subsequent grazing produced a series of changes in the understorey which are hard to assess today because very few detailed descriptions of the flora were made by early explorers or settlers. The *Eucalyptus albens* and *E. melliodora – E. blakelyi* woodland associations on the Central Western Slopes were drastically affected by early settlement; probably over 90% of these woodlands have been lost. Those areas not cleared have been subject to heavy grazing pressures. Moore (1966) describes some of the changes to understorey plant species over time due to grazing in these woodlands. Beginning with tall warm-season perennial grasses such as *Themeda australis* and *Poa caespitosa,* sheep grazing led to these being replaced by short, cool season perennials (other native species) and herbs. Further grazing led to the influx of cool-season annuals, mainly introduced species with Mediterranean origins. Superphosphate application further favoured annuals over perennial species of plants.

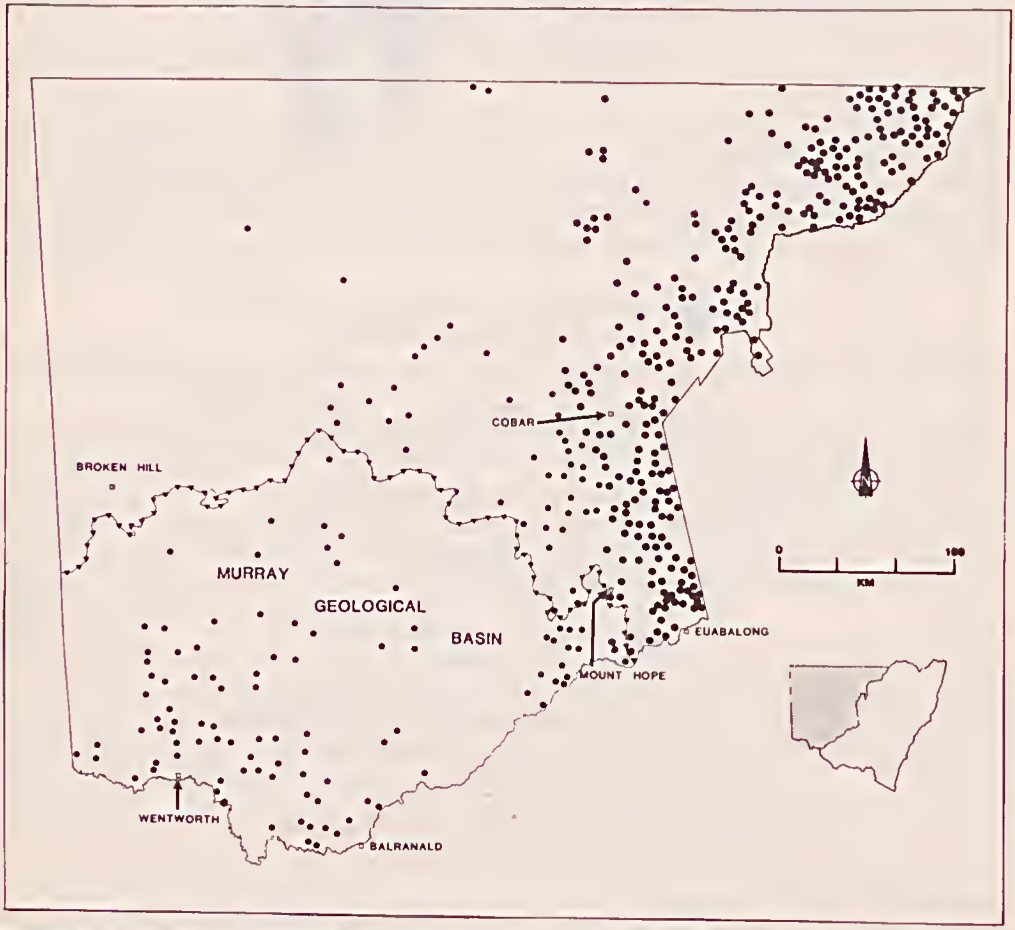


Figure 2. Location of clearing licences granted in the Western division 1984–1989 (from Pressey 1990).

The Central Division (Figure 1) has largely been cleared. This clearing is continuing to encroach into marginal lands to the west (Figure 2). Between February 1984 and November 1989 the Western Lands Commission granted clearing licences for over 560,000 hectares, although this overestimates the amount of land actually cleared (Pressey 1990).

The Western Plains of New South Wales have been grazed extensively since the 1830s, first by cattle then sheep (Heathcote 1965). Denny (1987) compares present-day vegetation with that noted by Sir Thomas Mitchell, Surveyor General of New South Wales, who explored the western river systems in the 1830s. An example is given for a site along the western section of the Murray River:-

Mitchell (1838): '*We crossed grassy plains bounded by sandhills on which grew pines [Callitris], and open forests of goborro (or box tree) prevailed very generally nearer the river...... the remarkable incident of this day's journey, was the discovery of an animal.....*'

The present-day vegetation at this locality has been highly modified. Much of the sand-hill vegetation has been cleared and some of the *Eucalyptus largiflorens* (Box Tree) has been ringbarked (Denny 1987). The animal discovered was the pig-footed Bandicoot (extinct by 1900). Denny records that 80% of the localities checked against Mitchell's notes in this region now have a decreased canopy and middle stratum in their vegetation.

Overgrazing by stock and other introduced animals, particularly the rabbit, combined with severe droughts and a lack of appreciation of the fragility of the environment, particularly the soils, have led to large scale degradation and changes in abundance of native plants and animals. The more palatable plants suffered most. For example, on the Riverina there has been a shift from chenopods to grassland and the reduction of such conspicuous perennials as Old Man Saltbush, *Atriplex nummularia* (Moore 1953). Five of the 11 native species of *Lepidium* (Brassicaceae) and six of the 32 species of *Swainsona* (Fabaceae) (Harden, in press) that have been recorded as occurring in western regions of New South Wales, are now threatened or extinct (Briggs and Leigh 1988).

Since settlement it is estimated that 56% (24 species) of all native mammals that once inhabited these regions are now extinct (National Parks and Wildlife Service 1982). These detrimental impacts on plants and animals in semi-arid regions have come about due to competition with introduced plants and animals, overgrazing and clearing for 'dry-land' cropping in an area with a high frequency of drought. Expanses of scalded country are a conspicuous legacy of past over-exploitation of the outback.

Specific causes of the decline of native vegetation

Grazing

Before European settlement there were no large 'hard-footed' animals or ruminants that could effectively eat dry grass. Domestic and feral animals introduced by European settlers placed increased pressure on native vegetation. Grazing has affected more than 60% of New South Wales and has been the major cause of decline in the vegetation of the State leading to a number of plant extinctions and major reductions in the range and abundance of species and associations (Benson 1989). Clearing has been the cause of decline but other important factors include: alteration of soil structure through compaction and of nutrients through application of fertilizers; erosion, particularly surrounding watering points or on erodible soils or steep slopes; senescence of palatable shrubs and trees with little or no regeneration (Chesterfield & Parsons 1985); changes to fire regimes and introduction of weeds, including the increase of native 'woody weeds' mainly found on the north-western plains. Another indirect effect of grazing is dieback. This refers to the phenomenon of death or decline in health of eucalypt trees in rural areas. In New South Wales it has been most severe on the tablelands and western slopes particularly on the New England Tableland on the Northern Tablelands (Williams & Nadolny 1980). The causes of dieback are currently being researched. Kile (1980) lists defoliation by insects, drought, tree age, soil salinity, mistletoe infestations and root pathogens such as the fungus *Phytophora cinnamomi* as factors associated with rural dieback.

Cropping and irrigation

Covering approximately 20% of New South Wales, cropping is most prevalent in the 'wheatbelt' of the Central Division and on coastal valleys and plains. Irrigation is common to many river systems with drastic effects on water supplies along the inland rivers. Because of the intensive nature of cropping there is usually total destruction of the native vegetation and it is difficult for it to re-establish. Intensive cropping has also led to soil structure decline. The nutrient status in soils is altered by ploughing and the application of fertilizers the latter leading to acidification in many places. Pesticides and herbicides affect non-target species in the surrounding natural biota. Introduced weeds, both terrestrial and aquatic, out-compete native species and reduce their abundance.

Salinity is a major problem in areas subject to cropping and grazing, for example, 920,000 hectares (mainly saline scalds) of the Murray–Darling Basin are affected by salination (Murray–Darling Ministerial Council 1989). Dryland salinity caused through the impact of rising water tables is estimated to be affecting 14–20,000 hectares in New South Wales (Keith Emery, Soil Conservation Service pers. comm.). In 1985, 9000 hectares of the Murray, Murrumbidgee and Wakool irrigation areas were visibly affected by salinity through rising water tables and this is projected to increase many times over the next 50 years (Peter Rooke, Water Resources Commission pers. comm.).

Forestry

As of June 1990 3,663,329 hectares (4.6%) of New South Wales was publicly managed for wood production, mainly on the east coast and tablelands but also the *Callitris* woodlands in the central parts of the State. Private lands are also logged. Logging practices range from selective logging to clearfelling for woodchips or pine plantations. These practices result in reduction in native forest areas, younger age classes, soil erosion (Forestry Commission of NSW 1988), changes in the microclimate affecting understorey species, introductions of weeds and pathogens (Ecos 1978) and changes in fire regimes (Fox 1990; Dickinson & Kirkpatrick 1987). Historically, the passing of the Forestry Act in 1916 played a major role in flora conservation by at least protecting areas from total clearing for agriculture. However, the recent trend towards more intensive forestry (Office of State Development 1989), could limit the conservation options for a number of forest associations and their constituent species on the tablelands, eastern escarpment and coast (National Parks & Wildlife Service 1990). By 2005 large areas of *Pinus radiata* plantations will have matured and increasingly they will replace native eucalypt forest in supplying both sawlogs and woodchips (Cameron & Penna 1988; Clark & Blakers 1989). In the interim, the future of the remaining unprotected, unlogged, aesthetically appealing, tall eucalypt forest growing on high-to medium nutrient soils will probably continue to be a topic of public debate.

Urban and industrial expansion

During the 1970s 60,000 hectares of land in New South Wales was developed for housing, industry or roads (Department of Arts, Heritage & the Environment 1986).

The figures for the 1980s are probably higher. Urban expansion is mainly affecting the coast. For example, in Sydney it is endangering a number of plant species, e.g. *Pimelea spicata, Grevillea caleyi, Eucalyptus camfieldii* and *Acacia pubescens*, and distinctive plant associations such as the Cumberland Plain woodland dominated by *Eucalyptus moluccana* and *E. tereticornis*. Besides direct destruction of the vegetation, weeds and pollution are major consequences of urbanisation. At Wentworth Falls in the Blue Mountains, the largest population of the endemic podocarp *Microstrobos fitzgeraldii* is threatened by excessive algal growth resulting from pollution in the catchment (Smith 1981; Brown 1990).

Mining and quarrying

The effects of extraction industries tend to be localised, but involve total loss of the vegetation. Revegetation depends on the nature of the mining and post-operative rehabilitation works. On the North Coast, beach sand-mining has eliminated some of the largest stands of littoral rainforest e.g. between Harrington and Crowdy Head (Floyd 1979). Underground mining for coal in the Sydney Basin can have detrimental impacts on swamps if hydrology changes as a result of land slumping (Young 1982; Nanson & Young 1983). Pollution and sedimentation downstream from mine sites can severely impede the health of aquatic and riverine vegetation.

Introduced plants

Approximately 20% of vascular plant species in New South Wales are naturalised exotics. Some of these have become major weeds to agricultural and natural environments. Characteristics of weeds include high colonising capacity, efficient dispersal and ability to reproduce rapidly (often asexually) (Groves 1986). Some of the major weed species in New South Wales affecting natural areas are: Lantana (*Lantana camara*), Boneseed and Bitou Bush (*Chrysanthemoides monilifera*), Privet (*Ligustrum* spp.), Camphor Laurel (*Cinnamomum camphora*), Crofton Weed (*Ageratina* spp.), Blackberry (*Rubus* spp.), English Broom (*Cytisus scoparius*) and Groundsel Bush (*Baccharis halimifolia*). Introduced members of the Asteraceae, Brassicaceae and Amaranthaceae are commonly invasive plants. *Salvinia molesta* and *Eichhornia crassipes* are major aquatic weeds. Eradication or control of weeds is expensive. Biological control provides the best option for controlling some weeds and investigations for some species are being carried out. The *Cactoblastis* moth – *Opuntia stricta* (Prickly Pear) case (Dodd 1959), remains the most successful example of biological control to date. Currently there are biological control studies underway for Bitou Bush *Chrysanthemoides monilifera* (John Scott pers. comm.), English Broom *Cytisus scoparius* (Hosking 1990) and *Lantana camara*.

Table 2 outlines the relative importance of various causes on the decline of natural plant associations in New South Wales. Evidence for decline or change in vegetation is outlined in Table 3. Reductions in abundance and distributions of plant associations are the most important aspects of the impact of European settlement.

Threats to plant species

In New South Wales, 14 plant species are reported as extinct; a further 12 plant species are no longer found in the State but exist in other parts of Australia; 213 plant species are threatened, of these 56 are endangered and 157 are vulnerable; 279 are rare and 26 plant species are presumed to be rare though their exact status is unknown (Briggs & Leigh 1988).

Table 2. Causes of decline or change to plant associations in New South Wales. Figures are derived from assessments made in Benson (1989).

Cause	Percentage of plant associations affected
Grazing/clearing	45
Cropping/clearing	18
Forestry	13
Changes in fire regime	6.5
Urban and industrial expansion	6
Drainage and irrigation	5.5
Mining and quarrying	3.5
*Competition with weeds	<2
*Recreational pressures	<2
*Herbicides and pollution	<2

Notes: * These causes of decline are likely to increase in the future.

Table 3. The proportion of plant associations subjected to various changes since European settlement. Figures are derived from assessments made in Benson (1989).

Nature of change	Percentage of plant associations affected
Reductions in range	
Minor reductions in range and/or abundance	36
Major reductions in range and/or abundance	29
Changes in age classes	
Younger age classes over much of an association's distribution (mainly due to forestry practices)	16
Older age classes over much of an association's distribution (mainly due to lack of regeneration due to grazing in pastoral areas. Also including delayed response including 'dieback'.)	10
Major alteration to the understorey	9 *
Increased abundance	1

Notes: *This is a conservative estimate because the understoreys of most plant associations have been altered to some degree. The term 'major' here implies loss of the majority of under storey plant species. Examples would be the box woodland associations on the western slopes.

Table 4. Causes for the extinction and threatened status of species of vascular plants in New South Wales derived by the author based on Leigh, Boden & Briggs (1984), unpublished works, and personal observation.

Cause	**X**	**E**	**V**	**Total**	**%**
Agriculture (grazing/cropping)	16	29	67	112	41
Forestry activities	-	2	10	12	4
Urban and industrial	1	5	14	20	7
Mining and quarrying	-	2	10	12	4
Change in fire regime/disturbance	1	5	23	29	11
Competition with introduced plants	-	1	4	5	2
Herbicides/pollution	-	2	1	3	1
*Collection pressures	-	3	6	9	3
**Low numbers	-	18	49	67	24
Recreation, e.g. trampling	-	-	2	2	1
Hydrological changes	-	4	-	4	2
Total	**18**	**71**	**186**	**275**	

Notes: Risk codes: X = extinct; E = endangered; V = vulnerable as defined by Briggs & Leigh (1988).
'Rare' species are excluded as they are not considered to be threatened.
Many species are affected by more than one cause.
* species threatened by uncontrolled collecting of whole plants or part thereof.
** species threatened because their population(s) are very small (usually less than 300). This may be natural or caused directly or indirectly by other factors.

The main causes for the extinction of or threats to plants in New South Wales (Table 4) are similar to those threatening plant associations — grazing and clearing. *Acacia carnei* is one of the many rare plants suffering from overgrazing. Research into its population dynamics in populations within Kinchega National Park reveal that there is little or no regeneration occurring from rootstock or seedling and there is advanced senescence of mature plants (Auld 1990). The main cause in its decline is rabbits. Where rabbits are less abundant, mature plants are far healthier and there is some recruitment from root-suckers (Auld 1990).

The 'low numbers' category includes species that had 'naturally' small populations (in the order of hundreds of individuals or less) at the time of European settlement and species that may have attained such small populations as a consequent of other causes. When they exist in small populations the long term viability of species is threatened due to genetic drift and consequent loss of fitness to adapt to change (Jarvinen 1982; Brown 1983). This could include possible rapid change in climate due to the Greenhouse Effect.

Some plant species may be endangered because they require particular environmental conditions such as disturbance to complete their life cycle, but now fail to get it due to human interference. Disturbance may take the form of fire, flooding, natural erosion and soil disturbance caused by burrowing animals. Both *Rutidosis heterogama* and *Olearia flocktoniae*, (Asteraceae) (presumed extinct until they were recently rediscovered on the North Coast) were located in disturbed sites; *R. heterogama* along a recently burnt fire trail in Bundjalung National Park, and *O. flocktoniae* on a recently graded roadside batter in a State Forest near Coffs Harbour.

Eriocaulon carsonii (Eriocaulaceae) illustrates a more indirect effect of European settlement. It only grows on a few mound springs in South Australia and one in the far north-western part of New South Wales. Many natural mound springs have been exploited for artesian water for stock and outback settlements, reducing the supply of water and hydrostatic pressures in the artesian basins. This has lead to a decline in the mound springs and the habitat of *E. carsonii* (T. Fatchen pers. comm.). The mound springs have also been physically damaged by the effect of stock trampling.

Uncontrolled collecting of some species is causing their decline. In New South Wales this is particularly so with orchids — *Sarcochilus fitzgeraldii* and *Phaius tancarvilliae* to name two. Australia's rarest eucalypt, *Eucalyptus recurva* (Crisp 1988), which has a population of six growing in two stands near Mongarlowe on the Southern Tablelands (R. Lembit pers. comm.), is threatened by collectors of seed and specimens. Collection pressure is a far greater threat to plant species in Western Australia where there is a substantial export cut flower trade, although this trade is closely monitored by the Western Australian Government.

Introduced naturalised flora

The large-scale invasion of alien plants began with European settlement in 1788. By 1804 the botanist, Robert Brown, had noted 29 introduced plants in Sydney (Groves 1986).

It is not surprising that Europe, Africa and Asia are major sources of alien plants considering the origin of the early settlers and their routes of immigration to Australia. Most of the settlers came from Britian, Ireland or Europe and they would have imported plants either intentionally or accidentally from their homelands. One example is *Lantana camara* (Verbenaceae) which as early as 1846 was present as an ornamental in the garden of Lady Innes at Port Macquarie on the north coast of New South Wales (Boswell 1981). It is now one of the most abundant weeds in coastal parts of the State and in south-east Queensland.

Kloot (1987b) suggests that, over time, plants from climatic regions more comparable with Australia have invaded. This explains the high numbers of naturalised, alien plants from the Mediterranean Region, the Americas and Africa.

Michael (1981) suggests that approximately 10 per cent of Australia's vascular flora are introduced (alien). Of the vascular flora of New South Wales 20 per cent are introduced and naturalised, (Table 1) (the term 'naturalised' is based on the definition of Thellung 1912 cited in Michael 1981). While only about five per cent of introduced plants have become naturalised in Australia and only approximately one per cent have become weeds (Michael 1981), alien plants have continued to have a significant impact on native flora. Asteraceae, Brassicaceae, Poaceae, Boraginaceae and Amaranthaceae are conspicuous in containing large numbers of alien, naturalised plants (Table 5). In western New South Wales approximately one third of all grasses are naturalised aliens (Cunningham et al. 1981).

Indigenous species also have invaded other parts of the continent: *Pittosporum undulatum* (Pittosporaceae), a native of coastal south-eastern Australia, is expanding its range and abundance in southern Victoria and in South Australia (Gleadow & Ashton 1981); *Acacia dealbata* (a native of eastern New South Wales) is spreading rapidly in Western Australia (Groves 1986) and *Acacia saligna* (a native of Western Australia) is expanding in some coastal regions of New South Wales.

Some of the invaders pose major threats to native vegetation. For many weeds, biological control is the only feasible solution but, as Groves (1986) points out, there is a need for more study into the genetics in weed populations to improve the theoretical base for biological control programs.

Fox & Fox (1986) consider that there is no invasion of natural communities unless there has been previous disturbance. One of the weeds threatening native vegetation

Table 5. Plant families with large numbers of alien naturalized species (from Kloot (1987b).

Dicotyledonous families	**No of species**
Asteraceae	153
Fabaceae (inc. Faboideae, Mimosoideae and Caesalpinioideae)	110
Brassicaceae	49
Caryophyllaceae	34
Solanaceae	38
Rosaceae	45
Lamiaceae	24
Scrophulariaceae	33
Monocotyledonous families	
Poaceae	208
Iridaceae	26
Cyperaceae	21

which comes closest to contradicting this view is *Chrysanthemoides monilifera*, the major weed along beaches in eastern and southern Australia. While this South African colonising species gained a strong foothold in Australia largely on disturbed sites, particularly coastal sand dunes, it is now displacing native species (Weiss 1983, Weiss & Noble 1984). It is detailed in a case study below.

Case studies

The following three case studies illustrate some influences of European settlement on plant communities and plant species, either directly through clearing or modification of the landscape, or indirectly through the introduction of alien plants that have become weeds and out competed native flora.

A threatened plant community: Brigalow

Acacia harpophylla F. Muell. ex. Benth. (Fabaceae) known as Brigalow spans from central northern Queensland to the North-Western Plains of New South Wales (Figure 3) (Sattler & Webster 1984). There are some isolated records further south in central NSW.

In Queensland it once covered about 4.7 million hectares, in New South Wales about 250,000 hectares (Pulsford 1984). In some Brigalow communities it is the only species in the upper stratum, and the understorey features few other plants. In others it is found with other *Acacia* species, *Eucalyptus*, or associated with semi-evergreen vine thickets (Johnson 1964, 1984). In moister regions and on better soils, Brigalow grows up to 20 m high. It mainly occurs on clay soils and in New South Wales these have developed from Quaternary alluvium over sedimentary strata (Isbell 1962, Pulsford 1984).

Unlike many of the other inland plant communities the bulk of the Brigalow country was left uncleared until after World War II. This was partly due to the difficulty of clearing Brigalow as it resprouts readily from rootstock and partly because of the major infestations of a pest, Prickly Pear (*Opuntia stricta*), over much of its range until controlled by the Cactoblastis moth. Favourable assessments of the soil under Brigalow for growing crops led to massive clearing operations in the 1950s and 1960s.

Brigalow is now one of the rarest plant communities in New South Wales. In Queensland only 0.5% of the estimated pre-settlement area of Brigalow is reserved and less than 1% in New South Wales (Sattler & Webster 1984, Pulsford 1984). Clearing still goes on, particularly in the northern parts of its range in Queensland that Lloyd (1984) views as Australia's last agricultural 'frontier'.

In the Narrabri–Bogabilla region of New South Wales only small amounts of Brigalow remain, usually in stands of less than 400 hectares (Pulsford 1984). A large stand of Brigalow survives 100 km north-east of Bourke, west of the Culgoa River. This population is several hundred kilometres west of the main band of Brigalow (Figure 3). Part of this population is under threat from clearing by lessees.

Improving the conservation status of Brigalow is now a priority of both the Queensland and New South Wales National Parks and Wildlife Services. Two small reserves have been established near the town of Narrabri in New South Wales and a number of others are being investigated. Protecting and reserving viable stands of Brigalow north-east of Bourke should be a priority.

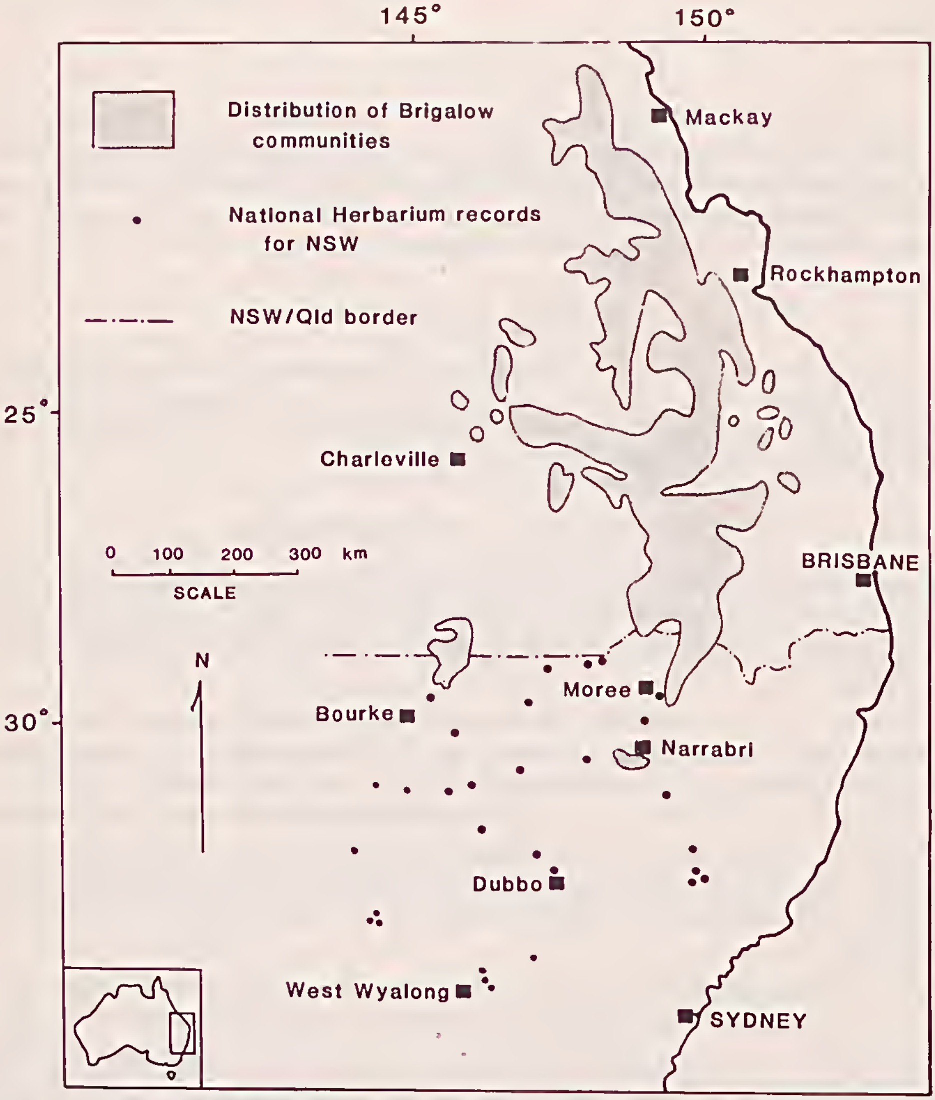


Figure 3. Distribution of Brigalow (*Acacia harpophylla*) in Queensland and New South Wales. Most of the larger stands near Narrabri and Moree in NSW have been cleared: only a few thousand hectares remain in scattered remnants. (Derived from Adamson & Fox 1981 and Pulsford 1984).

An endangered plant: Rutidosis leptorhynchoides

There are about 10 species of *Rutidosis* in Australia and four of these are listed as threatened (Briggs & Leigh 1988). *R. leptorhynchoides* F. Muell. (Asteraceae) is a bushy, perennial herb up to 30 cm high, flowering in the warmer months, particularly November and December. It was once more widely distributed in grasslands and woodlands in southern Victoria, centred on the basaltic Keilor Plain north west of Melbourne and in the Canberra–Queanbeyan districts on the Southern Tablelands of New South Wales.

The Victorian populations occur in communities dominated by Kangaroo Grass, *Themeda australis.* Most of the remaining sites near Melbourne are within railway reserves. One population has been observed to decrease from 100 plants to 11 plants over the last 10 years due to unsubstantiated causes (Leigh et al. 1984). In other recorded localities the species has become extinct.

In the Canberra–Queanbeyan area several populations of *R. leptorhynchoides* still occur, although it has suffered a substantial decline in its abundance due to urban expansion. One population on the outskirts of Queanbeyan has been protected in a small 2.2 hectare nature reserve. A few small populations in the Australian Capital Territory are threatened by urban development.

In Victoria, *R. leptorhynchoides* has mainly come under threat from grazing (Scarlett 1979). Fire could also be an important factor in its decline and Scarlett has suggested that summer burning regimes should be maintained or implemented. Further populations need to be protected in reserves and fenced off from grazing animals. Research into its response to grazing and fire is required.

An alien weed: Chrysanthemoides monilifera

Chrysanthemoides monilifera Norlindh (Asteraceae) is a 'pioneering' shrub that originates from South Africa where its six subspecies occur in a variety of habitats but commonly along the southern coastal areas of that country (Neser & Morris 1985). Two subspecies are present in Australia: *C. monilifera* subsp. *rotunda*, known as Bitou Bush, is established along the Central and North Coasts of New South Wales and the southern Queensland coast in regions of summer rainfall. *C. monilifera* subsp. *monilifera*, known as Boneseed, is found along the South Coast of New South Wales, in Victoria and in South Australia which receive higher winter rainfall.

Chrysanthemoides was first recorded in Sydney and Melbourne in the 1850s as a garden shrub (Gray 1976, Nicholls 1985). The main impetus for its spread was its use as a sand stabilizer on disturbed coastal sand dunes. This use continued even after it was listed as a noxious weed in other States, but ceased when its invasive properties were publicised and better appreciated. *Chrysanthemoides* now occupies 660 km or 60% of the New South Wales coastline, being dominant along about a third (Love 1985). Although approximately 35% of the coast is protected in conservation reserves, over 50% of the coastline in those reserves is affected by Bitou Bush or Boneseed (Love 1985).

The main native plant communities affected are foredune grasslands, dune scrub, dune forest, headland grassy heath and in particular small patches of littoral rainforest. Some rare plants such as *Cryptocarya foetida* (Lauraceae) are highly susceptible to competition with Bitou Bush (Dodkin & Gilmore 1985). Bitou Bush displaces the native shrub *Acacia longifolia* on coastal dunes on the South Coast of New South Wales because of its competitive advantage in the areas of seed production, rate of juvenile root and vegetative growth and an ability to expand vegetatively (Weiss 1983; Weiss & Noble 1984).

Groves (1985) highlights the need for integrated controls for Bitou Bush and Boneseed which would include biological control of seed production and growth vigor, selective use of herbicides, use of fire, and the promotion of indigenous plants to replace *Chrysanthemoides* as it is eliminated. A co-operative Commonwealth and States funded project into a biological control program for *Chrysanthemoides* has been underway for several years and several insect predators have been selected for further assessment and trialing (John Scott pers. comm.).

Conservation of the flora of New South Wales

The first legislation that afforded protection to plants in New South Wales was the *Wild Flowers and Native Plants Act* (1927). This only outlawed the picking of 'protected wildflowers' from Crown land or State Forest. It was replaced by the *National Parks and Wildlife Act* (1974) which, as far as the protection of plant species and their habitats is concerned, is not much better than previous laws (Prineas 1987). New South Wales lacks effective legislation that serves to protect threatened species of plants on all land tenures or recognises the importance of habitat conservation (although draft legislation has been prepared). In contrast, Victoria and Western Australia have strong legislation protecting scheduled plant species (Benson 1990).

Given the lack of effective laws directed specifically at protecting plants, the conservation of flora has mainly been achieved as a consequence of the establishment of reserves to protect scenic or recreational features. However, over recent years there has been more emphasis on reserving or managing lands for the plant communities and species that are poorly conserved or under threat.

In August 1990 the National Parks and Wildlife Service managed 3,854,807 hectares or 4.8% of the State for conservation in 308 conservation reserves (broadly shown on Figure 4). The Forestry Commission manages 137 Flora Reserves (located in State Forests across the State) covering 35,000 hectares (Forestry Commission of NSW 1989). Therefore as of August 1990 a total of 4.86% of New South Wales was specifically dedicated to the conservation of the natural environment.

Large tracts of indigenous vegetation remain outside conservation reserves on public lands and private lands. The public lands include State Forests, unalienated Crown land, travelling stock routes, Crown land reserves and some leasehold lands. Unfortunately, from the conservation perspective, there is now much greater competition for the use of these remaining public lands, whether it be using coastal Crown land for tourist or housing developments or harvesting timber from State Forests in a more intensive way than that practised in the past. Most of the Western Division, representing 40% of the State and incorporating half of the Western Plains and all the Far Western Plains botanical divisions, is leasehold land. Theoretically, there is some government control over land-use in the Western Division but as can be gleaned from Figure 2, clearing is still continuing.

Freehold lands, while in the main highly modified, also contain important vegetation. Some of this is poorly represented on public lands, for example coastal freshwater wetlands and some of the White Box (*Eucalyptus albens*) associations on the Western Slopes. There are presently two key State Environmental Planning Policies affording substantial protection to vegetation types: SEPP 14 covers coastal wetlands and SEPP 26 covers littoral rainforest. Additionally, SEPP 19 protects some of the urban bushland remnants of Sydney.

Of the 432 plant associations listed by Benson (1989) as occurring in New South Wales, 179 (42%) are well represented in reserves, 111 (25%) are either vulnerable or endangered and another 39 (9%) are not at all sampled in the reserve system. Table 6 assesses the conservation and threat status of the 18 major groups of plant associations. Generally, the groups that occur in the Central and Western Divisions are the least well conserved, only approximately 3% of land in these Divisions is protected in conservation reserves (compare Figures 1 and 4). Although there is a far greater proportion of land reserved on the coast and tablelands, i.e. the Eastern Division, it should be emphasised that this Division contains the most diverse, least disturbed and largest natural areas remaining in New South Wales. It is by no means adequately sampled, as those plant associations occurring on richer soils are scarcely represented in reserves, for example the tall eucalypt forests growing on basalt on the Northern Tablelands (Benson & Andrew 1990).

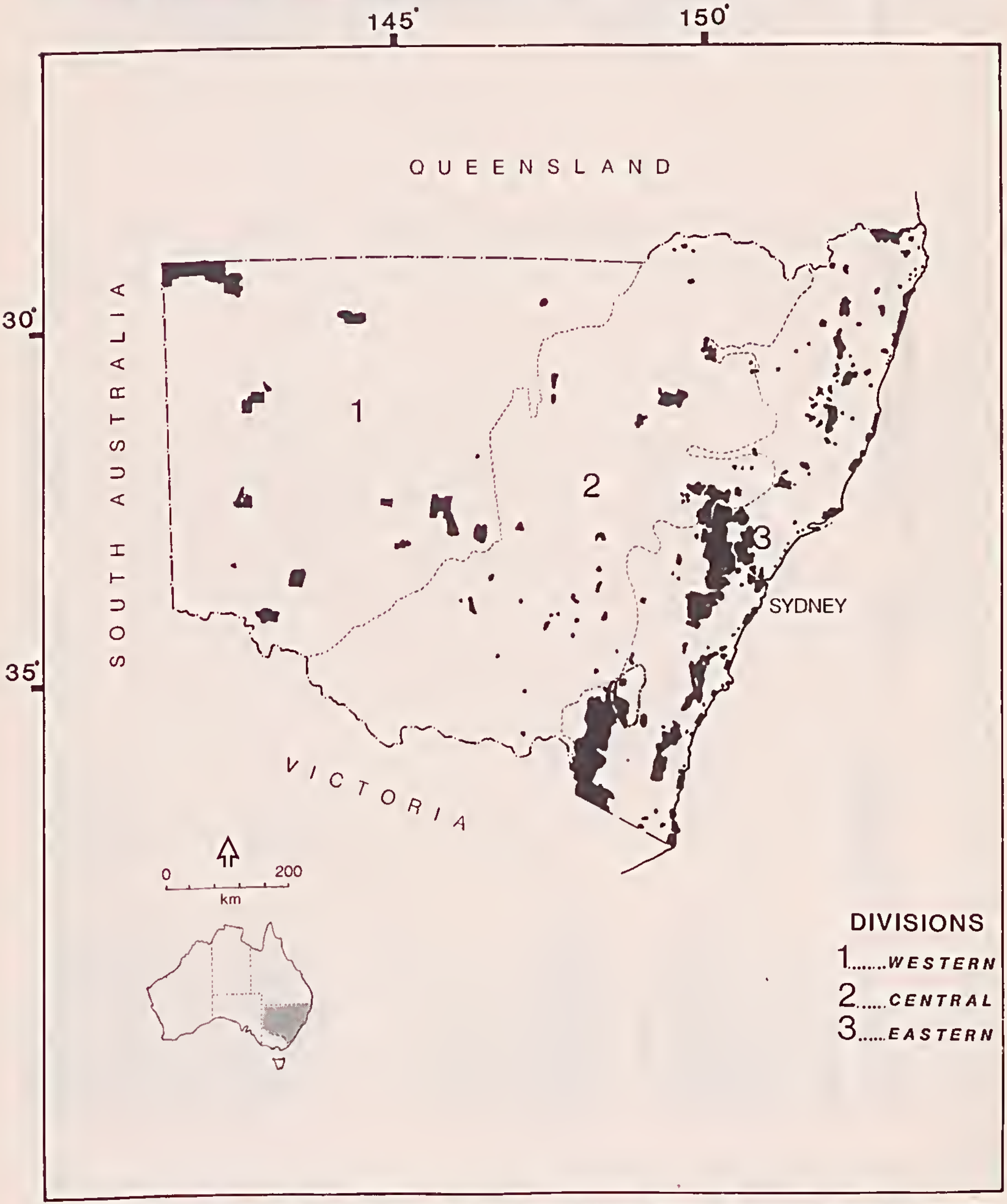


Figure 4. Conservation reserves held by the New South Wales National Parks & Wildlife Service as of 1990.

Table 6. Conservation status of major vegetation groups in New South Wales (from Benson 1989). The figures recorded in the columns refer to the number of plant associations within a vegetation group that are considered to be in a specific risk - conservation code.

			Risk - conservation code									
No.	**Vegetation group**	**No. of plant associations**	**E1**	**E2**	**E3**	**V1**	**V2**	**V3**	**N1**	**N2**	**N3**	**General conservation status**
1	Rainforest											
1(i)	Subtropical rainforest (incl. littoral)	20	1			3	1		6	9		Good: lowland remnants require special protection and management
1(ii)	Dry rainforest	12	3			1	1			4	3	Fair–good: western slopes associations not conserved
1(iii)	Warm temperate rainforest	14								4	10	Excellent
1(iv)	Cool temperate rainforest	11								2	9	Excellent
	Summary - rainforest	57	3	1		1	4	1		16	31	*Good: except for some lowland subtropical, littoral and western dry rainforest
2	Eucalyptus forests mainly on coastal lowlands, medium to high nutrient soils	38					4		5	14	15	Good–fair: some tall forest associations poorly conserved or vulnerable, particularly in forestry or agricultural regions
3	Eucalyptus forests mainly of the coastal lowlands and central tablelands on low nutrient soils	47				3	1	1	3	7	32	Excellent: except for some associations on aeolian sands

			Risk - conservation code									
No.	**Vegetation group**	**No. of plant associations**	**E1**	**E2**	**E3**	**V1**	**V2**	**V3**	**N1**	**N2**	**N3**	**General conservation status**
4	Eucalyptus forests of cooler highland climates (various soil types)	72	3			5	18		1	21	24	Fair: vulnerable associations occur in agricultural zones, particularly New England, Monaro
5	Ironbark forests and woodlands	16	2			2	3		1	6	2	Poor: mostly cleared for agriculture or logged
6	Box woodlands	25	8			6	5		6			Very poor: most vulnerable or endangered in agricultural lands
7	Inland mallee	10		1			3		2	3	1	Fair: some associations vulnerable to clearing for agriculture
8	Banksia and myrtaceous shrublands coastal lowlands - sands and clays	38					1			5	32	Excellent
9	Acacia and myrtaceous shrublands and related highland communities	22				2	1	1		5	13	Very good: except for some northern tableland associations
10	Alpine shrublands, sedgelands and herbfields (Kosciusko NP)	12					2				10	Excellent: but changing land use could threaten some associations
11	*Casuarina cunninghamia* forests	3					1			2		Fair: better conserved in east than in west
12	Inland acacia and casuarina shrubland/ woodlands	13	2	2			3		5	1		Poor: considering distribution; some associations endangered on north-west plains

No.	Vegetation group	No. of plant associations	Risk - conservation code									General conservation status
			E1	E2	E3	V1	V2	V3	N1	N2	N3	
13	Inland forests and shrublands dominated by 'rainforest' genera	4	1							3		Poor: one endangered, others widely distributed or poorly conserved
14	Halophytic shrubland of the southern plains	9	2			1	2			4		Very poor: little conserved some associations endangered or vulnerable
15	Natural grasslands	26	2				3		3	7	11	Fair: *Astrebla* and *Stipa* poorly conserved
16	Plant associations of the inland water-courses, floodplains and discharge areas	11					2	1	3	5		Very poor
17	Coastal freshwater wetlands and sedgelands	17					7			2	8	Excellent: sedgelands Poor: wetlands
18	Estuarine wetlands	12								6	6	Fair: generally not well conserved below high water mark, particularly sea grasses, and saltmarshes
	Grand total	**432**	**23**	**4**	**0**	**20**	**58**	**6**	**39**	**103**	**179**	

KEY

E = endangered V = vulnerable N = not threatened at this stage
1 = not conserved or, if so, to a very minor degree
2 = inadequately conserved (small areas conserved or geographical range poorly conserved)
3 = adequately conserved (large areas conserved over the major part of its range)

* Statements are made in the context of remaining vegetation. Since two-thirds of subtropical rainforest has been cleared it may never be possible to adequately sample many sites.

See Benson (1989) for the floristic classification of the vegetation of New South Wales.

The most poorly conserved vegetation groups in New South Wales are:

Central and Western Divisions

- box woodlands;
- inland semi-arid 'dry rainforest' remnants;
- halophytic shrublands;
- plant associations along inland watercourses and discharge areas;
- inland *Acacia* and *Casuarina* associations;
- natural grasslands.

Eastern Division

- tall *Eucalyptus* forest associations on higher nutrient soils on the coastal plains and escarpment;
- *Eucalyptus* forest associations of the cooler highland climates, particularly those on richer soils;
- most coastal freshwater wetland types and some estuarine wetland types.

Rare or threatened species

It is estimated that half of the 532 plant species registered as being rare or threatened in New South Wales (Briggs & Leigh 1988) are adequately reserved (Benson 1989), that is with over 1000 individuals being present in reserves. However, this does not necessarily imply these are being managed sympathetically for their long-term conservation.

Although rainforest and alpine plant associations combined cover less than 4% of the State, these contain approximately 20% of the rare or threatened plants (Table 7). These two vegetation groups are relatively well conserved.

While most rare or threatened plant species occur in the Eastern Division of the State, 44% of the vulnerable species are in the poorly reserved and heavily grazed or cropped Central and Western Divisions, thus following the trend identified above for plant associations. Because of the magnitude of the task of conserving viable and representative samples of all plant associations and plant species (particularly those that are rare or threatened) not yet adequately protected in New South Wales, priorities need to be set. It is suggested that the most threatened and poorly conserved plant associations be surveyed and viable samples reserved and managed sympathetically. For rare or threatened plant species, those that are most threatened and most distinct in the taxonomic sense should be given special emphasis in protection strategies. Some plant species and plant associations will require more detailed ecological research if they are to survive. Others may only require passive management and monitoring, particularly regarding the effects of different fire regimes and nutrient cycles.

There is still the opportunity to improve the conservation of the flora of New South Wales as, (unlike some other parts of the world), viable natural areas remain. An integrated approach is necessary, involving rational land-use decisions by government, protection of remnant vegetation through planning controls, reservation of important sites, taxonomic research, monitoring and ecological research.

While plant taxonomy has been given impetus by the *Flora of Australia* series, Parsons & Scarlett (1989) demonstrate that some genera are being much more extensively examined than others. The *Flora*, working to tight deadlines, leaves a proportion of taxonomic problems unresolved. That presents a deficiency in information needed for conservation programs.

Table 7. Number of rare or threatened plant species for major biogeographical habitat-provinces in NSW (from Benson 1989).

Habitat - Provinces	Risk Codes Extinct (X)	Endangered (E)				Vulnerable (V)				Rare (R)				Unknown Status (K)				Risk Code Totals					Total X+E+V +R+K=
		N	Ci	C-	Ca	N	Ci	C-	Ca	N	Ci	C-	Ca	N	Ci	C-	Ca	N	Ci	C-	Ca	TC	
Rainforest (All types)	1	9	7	4	0	1	3	11	1	0	6	18	17	2	0	0	0	12	16	33	18	67	80
Alpine (above treeline - Kosciusko NP)	0	0	0	0	0	0	0	3	1	0	0	17	13	0	0	1	0	0	0	21	14	35	35
Forests, heaths and swamps of high altitudes - tablelands	8	8	3	1	1	19	13	19	4	8	6	65	33	1	0	2	0	36	22	87	38	147	191
Forests, heath and swamps of lowland coastal zones	7	12	4	2	0	14	12	18	5	8	5	44	25	3	1	6	0	35	22	70	30	122	164
Forests, woodlands grasslands of western slopes & eastern plains (Central Division)	6	0	0	2	0	11	1	6	3	0	2	8	2	2	0	1	0	13	3	17	5	25	44
Semi-arid shrublands woodlands, grasslands, swamps of the western plains mainly Western Division	5	1	4	0	0	17	2	0	2	1	0	1	3	4	0	3	0	22	6	4	5	15	43
Total	27	30	18	9	1	62	31	57	16	15	19	153	93	*12*	*1*	*13*	*0*	*119*	*68*	*232*	*92*	*411*	*557*

For explanation of risk codes see Briggs and Leigh (1988)

Ci = inadequately conserved ie. less than 1000 individuals located in conservation reserves
Ca = adequately conserved ie. 1000 or more individuals located in conservation reserves
C- = known to be in reserve(s) but adequacy unknown
N = not known from any conservation reserves

Conservation reserves include all reserves managed by the NSW NPWS & Flora Reserves managed by the NSW Forestry Commission.

Note: These figures were derived by the allocation of species to one or more habitat - provinces depending on their distribution. In most cases species are restricted to only one habitat - province. Nevertheless the fact that some species are located in more than one habitat - province explains the inflated total figure of 557 compared to the figure for the number of rare or threatened plants listed for NSW which is 532. Species extinct in NSW but extant in other states are ignored. For example 10 species which once existed on the western plains now only occur in other states.

Some ecological research is now attempting to investigate some of the processes that can lead to the extinction of species (besides the obvious ones such as direct destruction through clearing the land). One aim is to extrapolate the results of studying functional groups and universal factors such as fire to a range of other species and associations of species. In addition to this type of research there remains the special need to investigate the population dynamics of threatened plant species that have been assessed as having declining populations. Also, research into the genetic variation within and between populations can play a major role in conserving species with small populations (Moran & Hopper 1983; Sampson et al. 1989).

I suggest that additional research into and application of biological control of 'environmental weeds' would, over the long term, be most beneficial (and cost-effective) for many native plant associations and species.

Until we gain more knowledge of our flora conservation decisions will continue to be based on 'qualified' subjectivity, particularly in choosing reserves and managing them. To conserve the flora of New South Wales, we will need more effective controls over excessive clearing of vegetation, river diversion and other developments. This can be achieved through more effective use of soil conservation, planning and wildlife protection legislation, and these need to be improved. The current growth of 'Land Care' in rural regions is encouraging, but the past losses of native vegetation have been so great that this may not be enough. Within the next 10 years most of the State's remaining tall old growth forests may be logged, much of the remnant vegetation on the Western Slopes will be further degraded and extensive clearing of the central and north-eastern sections of the Western Division may continue. Prevention of the continued widespread destruction of vegetation and the consequent loss of species will continue to depend on educating the public and its institutions about ecology and conservation, but it would also benefit by the enactment of improved legislation to protect habitats and the enforcement of all the relevent laws affecting nature conservation.

Acknowledgments

The author is grateful to Robert Dick who prepared Figure 1 from LANDSAT imagery, Ms Ifeanna Tooth for the preparation of other figures and to Dr Marilyn Fox, Doug Benson and Dr Annie Ross for their comments on the text.

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Manuscript received 11 February 1988

Revised manuscript received 2 January 1990

Manuscript accepted 7 March 1991

Bryophytes in the vicinity of Jenolan Caves, New South Wales

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Abstract

Downing, A.J.[1]*,Ramsay, H.P.*[1] *& Schofield, W.B.*[2] *(*[1] *School of Biological Sciences, Macquarie University, Sydney, NSW, Australia 2109;* [2] *Department of Botany, University of British Columbia, Vancouver, B.C., V6G 2B1, Canada) 1991. Bryophytes in the vicinity of Jenolan Caves, New South Wales* Cunninghamia *2(3): 371–384.* A total of 115 bryophytes (96 mosses in 56 genera, 18 hepatics in 12 genera, and one anthocerote) were collected from eight localities in the vicinity of Jenolan Caves, and two localities at Kanangra Walls in the Central Tablelands of NSW Geology, vegetation, climate and European settlement appear to influence distribution of bryophytes within the Jenolan Caves Reserve. The species list includes 5 new records of mosses for New South Wales and 18 additions to the mosses of the Central Tablelands. The bryophyte assemblage on limestone at Jenolan Caves is unique and distinctive, and many species present on limestone at Jenolan are either not present or not common on the sandstones and shales of the nearby Blue Mountains plateau.

Introduction

The Jenolan Caves are located in an elongated body of limestone in the Jenolan River Valley in the Great Dividing Range, 110 km west of Sydney and 30 km south-west of Katoomba, NSW (33°47'S, 150°05'E) (Figure 1). The blue-grey cliffs of Jenolan Caves Limestone form a massive barrier across the bottom of the valley, 790 metres above sea level. Three streams meet at a point below the Grand Arch (Figure 2) and flow eastward as the Jenolan River. Surveyors Creek flows from the south-west, and has cut through the limestone ridge to form the Grand Arch. Two streams, McKeowns Creek from the north, and Camp Creek from the south flow through the limestone, each creating a complex system of caverns for approximately 1 km on each side of the Grand Arch (Dunlop 1967). The Jenolan River runs through a young, steep-sided, v-shaped valley cut into the eastern side of the Great Dividing Range.

The main body of limestone at Jenolan is an ancient, Upper Silurian coral reef, composed of quite pure fossiliferous limestone, 96% to 99% calcium carbonate. Limestone lenses interbedded with shale are found 1.5 km to the east of Jenolan Caves (Chalker 1970).

The western valley sides are steep slopes derived from chert, with a spilite intrusion in the vicinity of Caves House. To the east a sequence of sediments and volcanics includes shales, pyroclastic rocks, cherts, tuffs, quartzite, sandstone and shaley limestone (McClean 1983). Alluvial deposits can be found in the valleys of McKeowns Creek and Camp Creek.

Climate at Jenolan Caves tends to be more extreme than that of Katoomba and the surrounding Upper Blue Mountains. Summer temperatures can exceed 40°C while winter temperatures can fall as low as -10°C. Temperatures on the plateau top are approximately 2°C to 3°C cooler than temperatures at the caves. Heavy snowfalls are not unusual in winter. Rainfall is evenly distributed throughout the year and ranges from 960 mm per annum at the Caves (790 metres a.s.l) to 1150 mm per annum on the plateau top at Jenolan State Forest, 1158 metres a.s.l (Bureau of Meteorology 1979).

Vegetation

Montane moist forest occurs at higher altitudes on moist, fertile, relatively deep clay and sandy loams. This open-forest is characterised by *Eucalyptus fastigata* and *Eucalyptus dalrympleana* subsp. *dalrympleana* occasionally with *Eucalyptus viminalis* and *Eucalyptus radiata* subsp. *radiata*. *Eucalyptus* woodland occurs on steep slopes, narrow ridges and gullies on quartzites, shales, cherts and tuffs. Characteristic species include *Eucalyptus fibrosa, Eucalyptus crebra, Eucalyptus eugenioides* and *Eucalyptus punctata* (Keith & Benson 1988).

Trees on shales in the immediate vicinity of the Grand Arch include *Eucalyptus punctata, Eucalyptus dives, Eucalyptus eugenioides* and *Eucalyptus radiata* subsp. *radiata*. Understory shrubs include *Bursaria spinosa, Oxylobium ilicifolium, Lissanthe strigosa, Persoonia linearis* and *Acacia falciformis*.

Vegetation on the limestone is relatively sparse *Poa* grassland, with scattered trees and shrubs. This contrasts sharply with shale, chert, rhyolite and tuff valley sides which are heavily wooded with little grass cover. Trees found on limestone include *Eucalyptus viminalis, Brachychiton populneus* (Kurrajong), *Acacia melanoxylon*, and *Ficus rubiginosa*. Shrubs on the limestones include *Acacia falciformis, Dodonaea viscosa, Swainsona galegifolia* and *Citriobatus multiflorus*. Climbing plants are more numerous on the limestones and include *Clematis aristata* and *Hardenbergia violacea*. Herbs include grasses (*Poa* spp., *Themeda australis*) and ferns (*Adiantum aethiopicum*). *Urtica incisa* (Stinging Nettle) is abundant in the vicinity of Caves House. Many exotic species, including *Rhododendron*, flowering cherries and roses have been planted in the gardens of the Caves House Hotel. Weeds and garden plants that have escaped from the gardens to invade the surrounding hillsides, include *Acer pseudoplatanus, Pinus radiata*, (Monterey pine), *Lunaria* (Honesty) and *Hypericum perforatum* (St. John's wort).

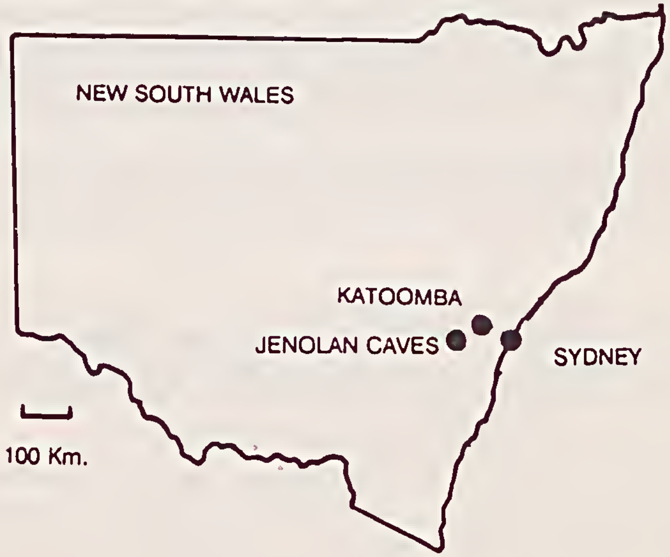

Figure 1. New South Wales showing location of Jenolan Caves.

Previous bryophyte collections from Jenolan Caves.

In the late 1890s, bryophytes were collected at Jenolan Caves by W. J. Blakely, J. H. Maiden, H. Malthouse and W. Forsyth. Among the earliest collections at the New South Wales National Herbarium are *Papillaria flavolimbata* (C. Muell. & Hampe) Jaeg. collected by H. Malthouse 572 (as *Papillaria cerina* (Hook. f. & Wils.) Par.) in August, 1898, *Tortula antarctica* (as *Tortula princeps*) J.H. Maiden (1898) 45, 368, Blakely (Oct 1899) 367, 476. Blakely collected *Thuidium sparsum* (as *Thuidium suberectum*) and *Papillaria amblyacis* (C. Muell.) Jaeg. (as *Meteorium amblyacis* (C.Muell.) Mitt. in June, 1899 (refer also to Watts & Whitelegge 1902, 1905). The National Herbarium (NSW) holds 28 mosses and 3 hepatics recorded as having been collected from Jenolan Caves (see Tables 1 & 2).

In 1901, W. J. Blakely, a gardener at Jenolan Caves and J. C. Wiburd, a guide for many years and caretaker from 1903 to 1932, published *A List of Plants Collected in the Vicinity of Jenolan Caves* (Blakely & Wiburd 1901). Included in the introduction by J. H. Maiden is the note 'Mr. W. Forsyth has the mosses in hand and a list of this and of other groups of plants not yet included in this preliminary Florula, may be expected in due course'. Unfortunately this list was never published and we have been unable to find the the manuscript of this list or the specimens on which it was based.

There are no detailed studies of bryophyte distribution on limestones in NSW, and indeed few published bryophyte species lists for particular localities (see Ramsay, Downing & Schofield 1990). This study was undertaken to determine the bryophyte species which occur on and in the vicinity of the Jenolan Caves limestone.

Results

Bryophytes were collected from numerous sites in the vicinity of Jenolan Caves during a number of field trips between October 1987 and December 1989. Collecting sites have been grouped into ten localities, eight in the vicinity of Jenolan Caves (Figure 2) and two in the vicinity of Kanangra Walls (Figure 3). Identifications were based on Sainsbury (1955), Scott & Stone (1976), Catcheside (1980), Scott (1985) and some more recent revisions of specific taxa including *Campylopus* (Frahm 1987) *Hypnum* (Ando 1982), *Orthotrichum* (Lewinsky 1984), *Macrocoma* and *Macromitrium* (Vitt & Ramsay 1985), *Mielichhoferia* (Shaw 1985), *Tortula* (Kramer 1988), *Thuidium* (Touw & van Haak 1990) and *Papillaria* (Streimann 1991). Reference was also made to Scott & Bradshaw (1986) for hepatics, and Streimann & Curnow (1989) for mosses.

A total of 115 bryophytes including 96 species of mosses (56 genera), 18 species of hepatics (12 genera) and one anthocerote were recorded (Tables 1 & 2) from the 10 localities. Results were based on 336 collections of mosses and 40 collections of hepatics including some earlier collections of H.P. Ramsay and D.G. Catcheside. Voucher specimens of all species collected will be deposited at the National Herbarium *(NSW)* for future reference and lists (as Appendices 1 & 2) will be held in the Royal Botanic Gardens Library for reference.

Details of the collecting localities are as follows; 1. *Binoomea Ridge Road* [BRR] (Figures 2, 4b): consists of steep hillside slopes, roadside cuttings and embankments of the Hampden – Jenolan Caves Road. Collections were made from the top of the plateau to Inspiration Point Lookout just above the Jenolan River. Subtrata include shales, cherts, tuffs, quartzite and sandstones. Vegetation consists of *Eucalyptus* woodland with grasses (*Poa* spp.), herbs, low shrubs and climbing plants such as *Clematis aristata* and *Hardenbergia violacea*.

Table 1. Mosses collected in the vicinity of Jenolan Caves, N.S.W. (see text for locality descriptions).

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	BRR	**BP**	**GAE**	**MCV**	**GAW**	**CA**	**SFT**	**OH**	**KW**	**BRC**
+*Amphidium cyathicarpum*						L				
+*Anoectangium bellii*						L				
Atrichum androgynum	x									
Barbula crinita				x	x	x				
+*Barbula luteola*						L				
+*Barbula unguiculata*	x			x		x				
**Bartramia papillata*	x			x				x		
+*Brachymenium preissianum*						L				
**Brachythecium rutabulum*	x		x	x		x	x			
+*Brachythecium salebrosum*	x				x	x				
**Breutelia affinis*	x		x				x	x		
Bryum argenteum			x		x	x				
Bryum billardieri	x					x	x	x		
Bryum campylothecium						x	x			
**Bryum capillare*	x					x				
Bryum clavatum (*B. erythrocarpoides*)						x		x		
Bryum dichotomum						L				
Bryum creberrimum	x				x					
Bryum pseudotriquetrum	x					x		x		
+*Bryum rubens*							x			
Bryum torquescens					x	x				
+*Bryum sp. nov.*			x							
Campylopus clavatus					x				x	x
+*Campylopus incrassatus*					x	x				
Campylopus introflexus	x		x	x			x		x	
**Ceratodon purpureus*	x			x		x		x	x	
Conostomum pusillum										x
Dawsonia longiseta			x							
Desmatodon convolutus					x	x				
+*Desmatodon recurvatus*					x					
Dicnemoloma pallidum	x		x				x			x
Didymodon torquatus				x						
Ditrichum difficile	x		x					x	x	
**Encalypta vulgaris*			L		L	L				
Fabronia australis						x	x			
+*Fabronia scottiae*						x				
Fissidens asplenioides					x					
Fissidens humilis						L				
**Fissidens leptocladus*			x	x	x	x				
Fissidens pungens						L				
Fissidens rigidulus		x								
**Fissidens taylorii*			L	L						
Fissidens vittatus	x		x	x		x				
Funaria apophysata					x					
Funaria glabra			L			L				
**Funaria hygrometrica*				x					x	
Gigaspermum repens			L	L		L				
Grimmia laevigata						L				
Grimmia pulvinata var. *africana*	x		x	x	x	x	x			
Grimmia trichophylla								x		
Gymnostomum aeruginosum	x		x			x				
Hedwigia ciliata	x		x			x	x			
Hedwigidium integrifolium							x			

Taxon	**1** **BRR**	**2** **BP**	**3** **GAE**	**4** **MCV**	**5** **GAW**	**6** **CA**	**7** **SFT**	**8** **OH**	**9** **KW**	**10** **BRC**
Hypnum cupressiforme var. *cupressiforme*						x	x	x		
+*Hypnum cupressiforme* var. *lacunosum*						L				
Hypopterygium rotulatum				L						
Lembophyllum divulsum				L		L				
**Leptodon smithii*			L	L		L				
Lopidium concinnum						L				
Macrocoma tenue subsp. *tenue*	x			x						
Orthodontium lineare	x									
Orthotrichum assimile	x				x	x				
Orthotrichum cupulatum var. *cupulatum*			L	L	L	L				
Papillaria crocea				x	x	x				
**Papillaria flexicaulis*			L	L	L	L				
Philonotis scabrifolia	x									
Philonotis tenuis	x									
+*Plagiomnium novaezealandiae*				L						
Pohlia nutans									x	
**Polytrichum juniperinum*	x		x							x
Pottia truncata						x				
Pseudoleskeopsis imbricata			L	L	L	L				
Ptychomitrium australe			x	x		x	x			
Racomitrium crispulum								x		
+*Racomitrium lanuginosum* var. *pruinosum*										x
Racopilum cuspidigerum var. *cuspidigerum*				x	x	x				
Rhacocarpus purpurascens										x
Rhaphidorrhynchium amoenum				x						
**Rhyncostegium tenuifolium*	x		x			x				
**Schistidium apocarpum*	x		x		x	x				
Schizomenium bryoides (*Mielichhoferia bryoides*)	x					x				
**Tayloria octoblepharis*									x	
**Thuidium cymbifolium*				L		L				
+*Thuidium sparsum*	x		x	x	x	x	x			
+*Tortella cirrhata*			L							
+*Tortella dakinii*					L					
**Tortula antarctica* (*T. princeps*)	x			x	x	x	x			
Tortula muralis			L		L	L				
Tortula norvegica				L						
Tortula pagorum					x	x	x			
Tortula papillosa				x		x	x			
+*Trichostomum brachydontium*			x	x		x	x			
Triquetrella papillata	x			x		x				
**Weissia controversa*	x		x		x	x				
Weissia controversa var. *gymnostoma*						L				
Zygodon intermedius						L				
Total	**31**	**1**	**30**	**32**	**27**	**59**	**18**	**10**	**7**	**6**

* = species collected at Jenolan Caves prior to 1987.
+ = additions to the species listed for Central Tablelands in Ramsay (1984).
L = occurred exclusively on limestone.
Species underlined = New records for N.S.W.

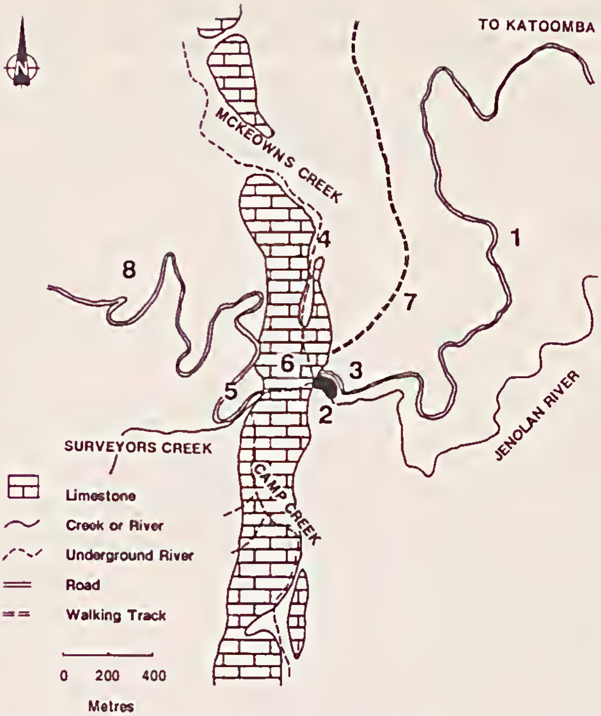

Figure 2. Jenolan Caves, NSW showing the location of collecting sites and limestone outcrops. Adapted from McClean, 1983. **1.** Binoomea Ridge Road, **2.** Blue Pool, **3.** Grand Arch East, **4.** McKeowns Valley, **5.** Grand Arch West, **6.** Carlotta Arch, **7.** Six Foot Track, **8.** Oberon Hill.

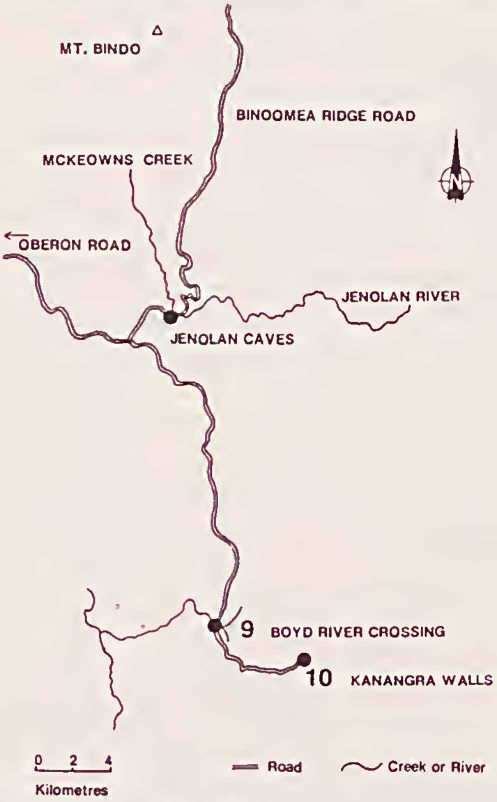

Figure 3. Collecting sites in the vicinity of Jenolan Caves.

Thirty nine species (31 mosses, 8 hepatics) were recorded along Binoomea Ridge Road. Most species collected along the road are relatively common on the sandstones and shales of the Blue Mountains. Two exceptions are *Philonotis scabrifolia* and *Atrichum androgynum*. Few epiphytes were collected, but more hepatics (8) were collected here than from any other locality.

2. *Blue Pool.* [BP] (Figure 2, 4a&b): an artificially created lake on the eastern side of the Grand Arch. The only bryophyte collected, *Fissidens rigidulus*, was growing under water, at 1.5 metres below the surface on a large, rounded, non-limestone cobble.

3. *Grand Arch East* [GAE] (Figure 2, 4a): covers the area on the eastern side of the Grand Arch, excluding the Blue Pool. Substrata include shale, limestone and rhyolite porphyry. Vegetation consists of *Eucalyptus* woodland on the lower hillsides, with *Ficus rubiginosa* on limestone outcrops, and taller eucalypts and tree ferns in moist and shaded positions.

Thirty three bryophytes (30 mosses and 3 hepatics) were recorded from this sheltered location where they are abundant on vertical, roadside rock walls, both on shale and limestone. Epilithic mosses (in particular *Orthotrichum cupulatum* subsp. *cupulatum*, *Grimmia pulvinata* and *Schistidium apocarpum*) and lichens are also abundant on the stone masonry of roadside walls. *Dawsonia longiseta* and *Reboulia hemisphaerica* were both collected from damp sand at the edge of a roadside drain below a shale rock wall. *Leptodon smithii* was collected from moist and shaded limestone boulders near the entrance to the Devils Coach House.

4. *McKeowns Valley* [MCV] (Figures 2, 5a–d): a narrow, canyon-like, limestone gully on the northern side of the Grand Arch, entered via the Devils Coach House (Figure 3). Grasses and shrubs predominate, with occasional trees of *Eucalyptus viminalis* and *Acacia melanoxylon*.

Thirty eight species (32 mosses, 6 hepatics) were collected in the valley where they obviously thrive in cool, moist and sheltered conditions. Epiphytic bryophytes, in particular, *Papillaria* spp., *Frullania* spp. and *Macrocoma tenue* subsp. *tenue* festoon the branches of shrubs and fallen logs.

One species of particular interest was *Plagiomnium novaezealandiae* which grows in luxuriant mats in seepages over rock. This species has not been reported previously from the Central Tablelands of NSW (Ramsay 1984). *Gigaspermum repens*, a species common in arid and semi arid areas of western New South Wales, occurs on soil in crevices in and between rocks.

5. *Grand Arch West* [GAW] (Figures 2, 4c): covers the western side of the Grand Arch, including Jenolan Caves House (gardens and stone walls) and the No. 1 carpark. Substrata include spilite and limestone. This sheltered position contains many exotic trees, shrubs, and introduced weed species. *Poa* grassland is present on the limestone at the rear of the hotel. Construction of buildings, roads, gardens and car parks has caused significant changes to the natural vegetation.

Thirty three species (27 mosses, 1 anthocerote, 5 hepatics) were collected on the western side of the Grand Arch. *Encalypta vulgaris*, a calcicolous moss, is present on damp rock on the western wall of the Grand Arch, and on limestone walls of the gardens. *Targionia lorbeeriana*, a thallose hepatic which we have not previously collected in the Blue Mountains, grows on damp soil in sheltered locations in the Jenolan Caves House garden, and under the shelter of overhanging vegetation along trackside embankments. *Anthoceros laevis*, an anthocerote, was also collected from similar environments. *Tortula antarctica* (*T. princeps*) and *Barbula crinita* are common on soil in the garden. *Marchantia polymorpha*, a thallose hepatic and *Bryum*

Table 2. Hepatics and anthercerote collected in the vicinity of Jenolan Caves, NSW (see text for locality descriptions).

Taxon	**1** **BRR**	**2** **BP**	**3** **GAE**	**4** **MCV**	**5** **GAW**	**6** **CA**	**7** **SFT**	**8** **OH**	**9** **KW**	**10** **BRC**
#*Anthoceros laevis*					x	x				
Asterella drummondii						L				
Cephaloziella exiliflora	x			x			x			
Chiloscyphus semiteres	x							x		
Fossombronia wondraczekii	x									
Frullania falciloba	x			x	x	x				
Frullania pentapleura				x		x				
Frullania probosciphora	x			x		x				
Frullania squarrulosa							x			
Lophocolea biciliata	x				x					
Lophocolea bidentata	x		x							
Lophocolea novae-zeelandiae					x					
Lunularia cruciata	x									
**Marchantia polymorpha* var. *aquatica*					x					
Metzgeria decipiens			x							
Metzgeria furcata						x				
**Porella crawfordii*				x						
Reboulia hemisphaerica			x							
Targionia lorbeeriana				x	x					
Total	**8**	**0**	**3**	**6**	**6**	**6**	**2**	**1**		

* = species collected at Jenolan Caves prior to 1987.
L = species collected exclusively on limestone.
# = anthocerote.

argenteum, a small, tufted moss, are two cosmopolitan bryophytes collected from the vicinity of Jenolan Caves House and the No. 1 carpark.

6. *Carlotta Arch* [CA] (Figure 2, 4a): includes exposed sites on limestone in the vicinity of the Carlotta Arch and the No. 2 carpark. Vegetation on limestone near the arch is sparse and dominated by shrubs, grasses and climbing plants. In the vicinity of the No. 2 carpark the area includes a number of rock outcrops sheltered by tall trees including *Eucalyptus globulus* subsp. *bicostata* and *Eucalyptus viminalis*.

Sixty five species (59 mosses, 5 hepatices, 1 anthocerote) were collected in the vicinity of the Carlotta Arch and the No. 2 Carpark. Of particular interest was *Gymnostomum aeruginosum*, a calcicolous species often associated with bat guano, growing in damp limestone dust in a small cave bordering the Carlotta Arch. Three of the hepatics (*Frullania* spp.) are epiphytic on *Bursaria spinosa*. One thallose hepatic, *Asterella drummondii*, and the anthocerote *Anthoceros laevis* both grow on the damp soil of a trackside bank, protected by overhanging *Poa* grass tufts. Epilithic mosses such as *Pseudoleskeopsis imbricata*, *Orthotrichum cupulatum* var. *cupulatum*, *Grimmia pulvinata* are abundant.

7. *Six Foot Track* [SFT] (Figure 2): a track in a shale band on the steep valley sides to the east of the Devils Coach House. Vegetation consists of *Eucalyptus* woodland, with occasional shrubs. Much of the ground is covered in thin plates of shattered rock. Lichens are abundant on exposed, flaking boulders.

Table 3. Bryophytes recorded at the National Herbarium of NSW as having been collected from Jenolan Caves prior to 1987 but not collected in the course of this study.

1. *Breutelia pendula* (probably incorrect identification)
2. *Dicranoloma dicarpum*
3. *Hypnodendron vitiense*
4. *Leptotheca gaudichaudii*
5. *Papillaria amblyacis*
6. *Papillaria flavo-limbata*
7. *Pyrrhobryum parramattense*
8. *Wijkia extenuata*
9. *Symphyogyna interrupta*

Twenty bryophytes (18 mosses and 2 hepatics) were collected from shales along the Six Foot Track. *Hedwigidium integrifolium* and *Hedwigia ciliata* are both common on rock, together with dense patches of lichens. *Campylopus introflexus* is most conspicuous on the ground, growing on charcoal and on soil between rock fragments.

8. *Oberon Hill* [OH] (Figure 2): consists of sheltered roadside embankments of the steep hillside on the western side of McKeowns Valley, along the Oberon Road. Moist montane forest has a dense cover of grasses (including *Poa* spp.) and herbs. There are very few rock outcrops and very little exposed soil.

Eleven species were collected on the Oberon Hill (10 mosses, 1 hepatic). Bryophytes were collected from exposed roadside embankments. We have not previously collected *Grimmia trichophylla* in the Blue Mountains and it is rare in the Central Tablelands (Ramsay 1984). Although *Racomitrium crispulum* is common in the vicinity of Megalong Valley, we have found it only at this site in the Jenolan area.

9. *Kanangra Walls Lookout* [KW] (Figure 3): the exposed sandstone plateau overlooking Kanangra Walls.

Seven mosses (no hepatics) were collected from the sandy soils of the Kanangra Walls Lookout. Most grow in compacted sandy soil by the side of walking tracks. Three species, *Funaria hygrometrica, Pohlia nutans* and *Tayloria octoblepharis* were collected at Kanangra Walls but were not collected from any of the Jenolan Caves sites although all three species are common on sandstones and shales in the Blue Mountains.

10. *Boyd River Crossing* [BRC] (Figure 3): an area of *Eucalyptus* woodland and heath on granite, approximately 7 km north of the Kanangra Walls Lookout.

Six mosses were collected from the Boyd River Crossing. Bryophytes and lichens are abundant in and around heath plants on a large area of exposed granite moist with seepage. Two species, *Conostomum pusillum* and *Racomitrium lanuginosum* var. *pruinosum* were not collected in the immediate vicinity of Jenolan Caves, and we have not previously collected *Racomitrium lanuginosum* var. *pruinosum* in the Blue Mountains area. *Racocarpus purpurascens* was collected from an exposed boulder in *Eucalyptus* woodland adjoining the heath. This species is common in the Blue Mountains area on sandstone, but was not collected from any other site at Jenolan during this study.

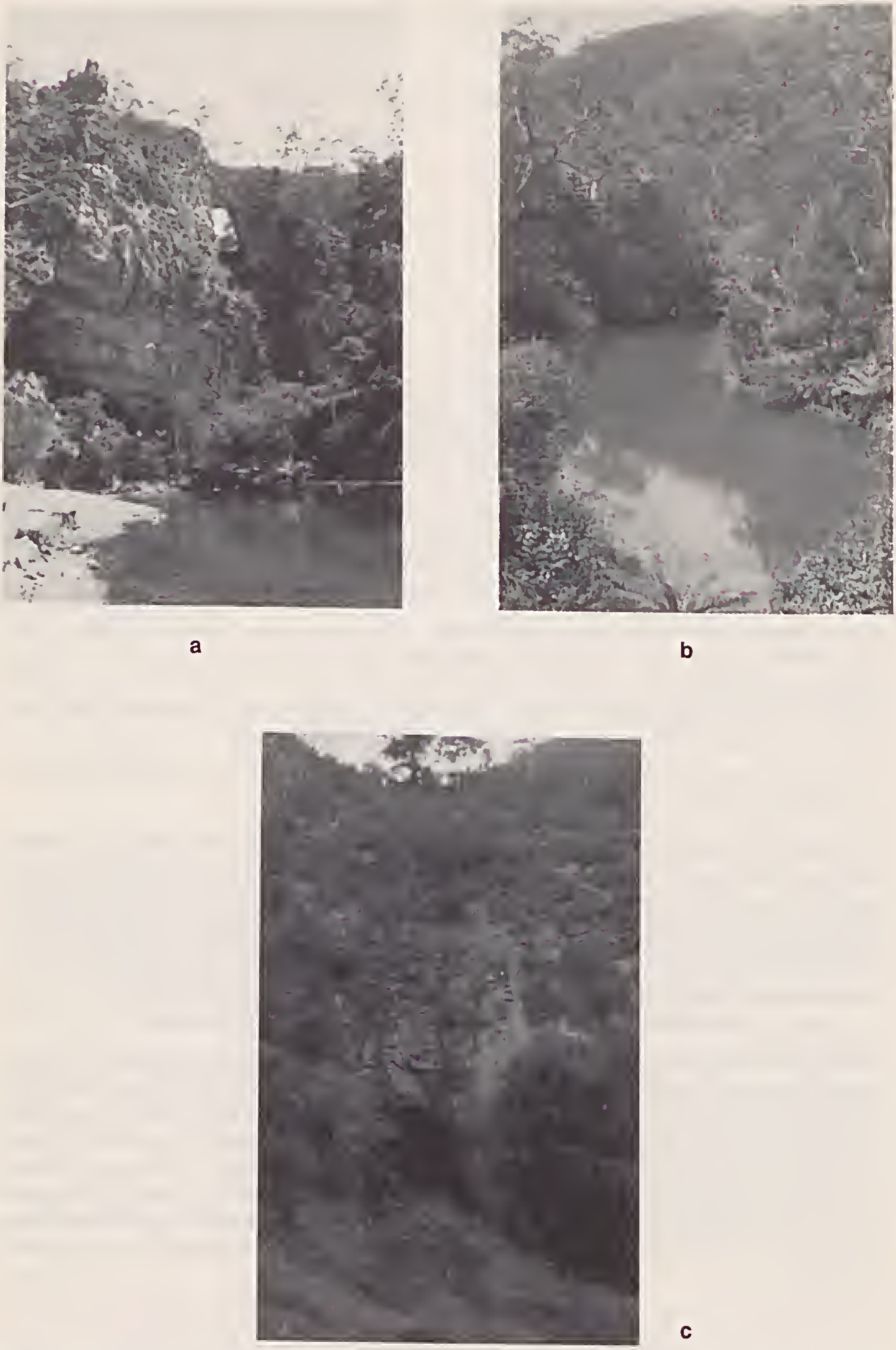

Figure 4. Jenolan Caves area. **a.** Blue Pool, Grand Arch and Carlotta Arch. **b.** Blue Pool, and *Eucalyptus* woodland typical of vegetation along Binoomea Ridge Road. **c.** Grand Arch, western face.

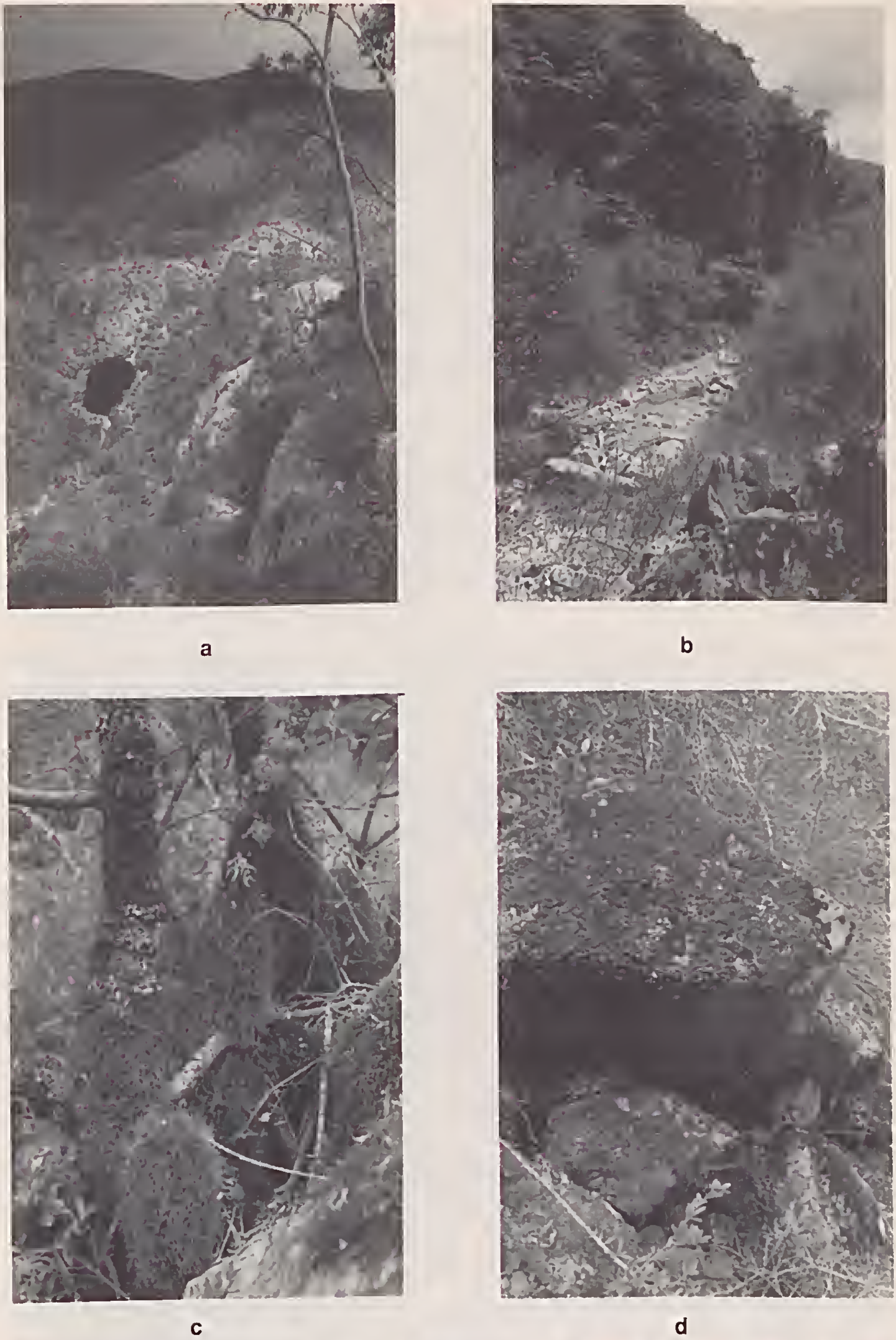

Figure 5. McKeowns Valley. **a.** McKeowns Valley leading to the Devils Coach House viewed from Oberon Hill. **b.** Limestone outcrops along the dry creek bed of McKeowns Valley. **c.** Mosses (*Papillaria* spp.) festooning bases of shrubs in McKeowns Valley. **d.** Mosses (*Orthotrichum cupulatum* var. *cupulatum*, *Tortula antarctica* and *Grimmia pulvinata* growing in abundance on limestone boulders in McKeowns Creek Valley.

Discussion

More bryophyte species were recorded from localities that included limestone (Grand Arch East, McKeowns Valley, Grand Arch West and Carlotta Arch) than from localities based on non-limestone substrata (Binoomea Ridge Road, Six Foot Track, Oberon Hill, Kanangra Walls and Boyd River Crossing) (Tables 1 & 2). In the Jenolan Caves area twenty eight species (27 mosses and 1 hepatic) were recorded exclusively from limestone substrata. (Tables 1 & 2). However, not all species recorded only from limestone at Jenolan are exclusively calcicolous e.g. *Leptodon smithii* occurs as an epiphyte on the trunks of trees and *Hypopterygium rotulatum* and *Lopidium concinnum* can be found on a variety of substrata in closed forests of the Blue Mountains. None of the species collected from limestone is endemic to Australia. Some species such as *Encalypta vulgaris* and *Amphidium cyathicarpum* are widespread, while others such as *Pseudoleskeopsis imbricata* and *Orthotrichum cupulatum var cupulatum* are restricted to Australia and New Zealand.

Three moss families (Pottiaceae, Bryaceae, Fissidentaceae) were well represented. From the Pottiaceae, 16 species in 9 genera (*Anoectangium, Barbula, Desmatodon, Didymodon, Pottia, Tortella, Tortula, Weissia and Trichostomum*) were collected. From the Bryaceae 16 species in 4 genera, (*Brachymenium, Bryum, Orthodontium, Pohlia*) were collected. More species of *Bryum* (12, including one undescribed species) were collected than of any other genus. From the Fissidentaceae, 7 species of *Fissidens* were collected.

Five species are reported as new records for NSW (*Anoectangium bellii, Bryum rubens, Bryum* sp. nov., *Tortella dakinii, Trichostomum brachydontium*) and eighteen species (Tables 1& 2) have been added to the list for the Central Tablelands of NSW (Ramsay 1984, Ramsay et al. 1990).

Twenty two of the 31 bryophytes previously collected at Jenolan Caves and held at the National Herbarium (NSW) were re-collected during this study (Tables 1, 2). We suggest the following possible explanations for the absence of 9 previously collected species from our collections:

a. Identification of one species is probably incorrect (Table 3).

b. Human influence has caused changes to habitat that may have affected bryophyte distributions. Construction of the bridge over McKeowns Creek and the damming of the Jenolan River valley downstream from the Grand Arch have produced the Blue Pool. Rampant weed growth on the western side of the Grand Arch may also have changed the nature of bryophyte assemblages. These changes may also have produced habitats suitable for colonisation by exotic bryophyte species, e.g. *Lunularia cruciata, Marchantia polymorpha* var. *aquatica*.

c. It is possible that some specimens were collected from sites outside our selected study area and lumped together under the name Jenolan Caves. Most of the species not collected in our survey are species which would be common in sheltered gullies in moist closed-forest e.g. in Megalong Valley (*Pyrrhobryum parramattense, Dicranoloma dicarpum, Wijkia extenuata, Papillaria amblyacis, Papillaria flavolimbata*) rather than on exposed rocky outcrops in *Eucalyptus* woodland of the Jenolan Caves area today. In the late 1880s the Six Foot Track was surveyed from Katoomba, through Nellies Glen, Megalong Creek, Coxs River, Little River and over Black Range to Jenolan Caves (Smith 1984). It seems likely that in the late 1890s, botanists such as Maiden and Blakely would have travelled to Jenolan via the Six Foot Track and that some of the collections listed here may have been from the closed-forests of Megalong Valley near the start of the journey to Jenolan Caves.

Acknowledgments

We would like to thank the Jenolan Caves Scientific Committee for permission to work in the Jenolan Caves Reserve. We have particularly appreciated the encouragement, advice and assistance of Ernst Holland. We are grateful to David Catcheside, Graham Bell, Heinar Streimann, John Spence and Elizabeth Brown for assistance with the identification of a number of difficult species. Patricia Selkirk has supported the project from the outset, and has assisted us with field trips and advised on the text. We are most grateful to Ron & Margot Oldfield, Jeannette Gregory, Kevin Downing and Jean Edgecombe for their assistance on field trips.

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Manuscript received 9 October 1990
Manuscript accepted 7 March 1991

Sex ratios in dioecious Australian grasses: a preliminary assessment

H.E. Connor and S.W.L. Jacobs

Abstract

Connor, H.E.[1] & Jacobs, S.W.L.[2] ([1] Centre for Resource Management, University of Canterbury, Christchurch, New Zealand; [2] National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia 2000) 1991. Sex ratios in dioecious Australian grasses: a preliminary assessment. Cunninghamia *2(3): 385–390.* Four grass genera in Australia are dioecious: *Spinifex, Zygochloa, Pseudochaetochloa* and *Distichlis*. In three genera the sex ratio equals or approximates the primary sex ratio of 1M:1F but in *Distichlis* the populations at most sites consist exclusively of female plants. Australia offers the best opportunity in the Old World to collect in nature basic information to advance knowledge of dioecism in the Poaceae. This preliminary assessment is intended to generate interest in that topic.

Introduction

The primary sex ratio males:females = 1 was established by Fisher (1930) and the theory was extended by Shaw & Mohler (1953). A recent re-examination of the topic is that of Bull & Charnov (1988). For dioecious plants data on sex-form frequencies are derived from counts in natural populations or from genetic experiments. Because of the scarcity of sex-form frequency data in the grasses, Connor (1987) advocated their collection to help substantiate current theories or substitute for them. In Australia four genera of grasses are dioecious: *Spinifex*, three species, and *Zygochloa*, monotypic (Spinificinae, Paniceae); *Pseudochaetochloa*, monotypic (Cenchrinae, Paniceae), and *Distichlis*, one species (Monanthochloinae, Eragrostideae). This is the highest concentration of dioecious grass genera in the Old World; in the New World about 20 genera are dioecious with at least 16 of them present in Mexico.

In Australia sex-form frequencies are known for *Spinifex hirsutus* and *S. sericeus* (Kirby 1988; McDonald 1983; Maze & Whalley 1990a). Here we report those for *S. longifolius*, and for *Distichlis*, *Pseudochaetochloa*, and *Zygochloa*. Three conform to 1M:1F; the exception is *Distichlis distichophylla* where females alone are found at many sites in Victoria. None of these results assists in the formulation of better models describing sex ratios in wind-pollinated dioecious plants.

Methods

Populations of four of the six Australian dioecious grass species were examined in New South Wales, Victoria, and Western Australia (Tables 1 & 2).

As all species were at anthesis, or nearly so, sex-forms and their frequencies were determined by inspection of single plants (genets) along transects whose lengths were determined by the size of the population. *Pseudochaetochloa* frequency was determined in a rectangular quadrat.

In *Distichlis* two other counts were made at most sites: (i) the number of spikelets in 10 inflorescences of the sex-form, and (ii) the number of florets per spikelet in the penultimate spikelets of five inflorescences. These allow an estimate to be made of differences in resource investment at an early stage of the reproductive cycle.

Results

Distichlis distichophylla (Labill.) Fassett

This short, rhizomatous grass tends to form long narrow strips. In Victoria and New South Wales it was at anthesis at all sites in early December 1987. Stigmas in females are purple, up to 5 mm long, and emerge from the apex of a very slightly opened floret; the sterile anthers, c. 0.1 mm long on filaments up to 2 mm long, are not exserted. In male flowers, tailed anthers c. 3 mm long are borne on filaments c. 4 mm long, but the stigma-styles, c. 2 mm long, are not evidently exserted.

Sex-form frequencies were collected from nine sites, all but one in Victoria (Table 1). At two localities, both male and female plants were found together; everywhere else all populations consisted of female plants only. On the flat, salt-marsh margin of the Betka River, Malacoota, Victoria, one population was exclusively female, but a second, some 50 m upstream, contained 20M and 2F. Ecological differences could not be detected that would account for such a major change.

At Lake Tyer's Boat Ramp No. 2, Victoria, there were six colonies, three of each sex, and judging from their lengths (M = 50 m, 15 m, 5 m; F = 50 m, 5 m, 5 m) they probably represented an initial migration of both sex-forms followed by fragmentation into the present subpopulations. Mixed through one female patch were occasional small male plants. This is the only site at which both sex-forms are present in something approaching 1M:1F.

Exclusively female populations were found at four localities; the sole population exclusively of male plants was found at Lakes Entrance, Victoria.

The mean numbers of spikelets per inflorescence and florets per spikelet are not significantly different between sex-forms in *D. distichophylla* (Table 1).

Spinifex longifolius R. Br.

This Western Australian stoloniferous plant of coastal sand dunes was at pre-anthesis in early June 1988 at Cable Beach. Female inflorescences are globular heads, about 20 cm in diameter, of sessile racemes reduced to a single spikelet on a stout bristle 5–10 cm long. Male inflorescences are terminal clusters of racemes of two-flowered spikelets. There were no problems with sex-form recognition. In the single sample examined the sex ratio was 1M:1F (Table 2).

Zygochloa paradoxa (R. Br.) S. T. Blake

Shrub-like, wiry, and rhizomatous, this is a tall species of inland sand hills. In western New South Wales in December 1987 it was still at anthesis even though seeds were present in some female florets. The male floret opens widely, and versatile, 3 mm long, maculate orange, polliniferous anthers are exserted on filaments about 5 mm long. In female florets stigmas are about 5 mm long and are exserted apically from the floret; the small (0.5 mm) sterile, white anthers emerge at the floret apex. In these characters of anthesis *Zygochloa* behaves like *Spinifex* as described by Connor (1984). In *Z. paradoxa* there is a slight excess of females reflected in their overall frequency of 0.57. In total there is a fit to 1:1 (Table 2), and the significant heterogeneity ($X^2_4 = 10.36$) is substantially contributed by the sample listed as Lake Menindee (b). No ecological differentiation for sex-form within sites was evident.

Table 1. Sex-form frequencies and allied data for *Distichlis distichophylla*.

	No. plants		Transect length m	Mean spikelets/ inflorescence		Mean florets/ spikelet		Herbarium collections
	M	F		M	F	M	F	
VICTORIA								
1. Betka River, (a) Malacoota	0	21	30	-	5.0	-	7.4	S.J. 5505, 5506
37°36'S (b) 149°45'E	20	2	30	3.9	-	7.8	-	
2. French (a) Narrows	0	19	10	-	3.9	-	5.8	S.J. 5507, 5508
37°48'S (b) 148°35'E	0	19	12	-	3.6	-	8.4	
3. Lake Tyers Boat Ramp No.2 37°50'S 148°06'E	3*	3*	Colonies of each sex up to 50 m	3.7	4.6	9.2	6.6	S.J. 5509, 5510
4. Lake Tyers Fishermans Landing 37°50'S 148°05'E	0	1*	Colony c. 75 m	-	3.8	-	7.8	S.J. 5511, 5512
5. Lakes Entrance 37°52'S 148°00'E	1*	0	Small colony < 10 m	3.3	-	7.6	-	S.J. 5513
6. Metung Shaving Point Reserve 37°55'S 147°50'E	0	2*	Colonies c. 10 m	-	-			S.J. 5514, 5515
N.S.W								
7. Lake Cargelligo 33°18'S 146°20'E	0	2*	Small colonies < 10 m	-	4.6	-	5.4	S.J. 5524
Mean				3.63±0.18	4.25±0.23	8.2±0.50	6.86±0.48	
				t = 1.747 NS		t = 1.732 NS		

Note: *Colonies not individual plants. Specimens from all populations are in National Herbariium of NSW and duplicates at CHR; numbers preceded by S.J. are S.W.L. Jacobs' collecting numbers.

Pseudochaetochloa australiensis A. Hitchc.

In this shortly rhizomatous, inland, endemic perennial, the two sex-forms are so different that they were originally described in separate genera (T. D. Macfarlane, pers. comm.). At Wyndham, Western Australia, some male plants were at anthesis in early May 1988 with the yellow anthers partly extruded apically; in the female plants some spikelets had white stigmas long-exserted apically through the dense white indumentum surrounding the involucre, while other spikelets in the same inflorescence bore mature caryopses. In the one population sampled the sex ratio did not depart from 1M:1F (Table 2).

Discussion

Sex ratios are now known for all dioecious Australian grasses even though some estimates are preliminary. In general they fit a 1M:1F ratio, but the data should not be extended beyond their limits; those for *D. distichophylla* are extensive enough to be reliable, and those for *Z. paradoxa* will reflect the composition of populations in inland New South Wales, but the sex ratio based on a single sample of *Pseudochaetochloa* must remain only a preliminary indication.

The sex ratio for *Spinifex longifolius* in Western Australia was 1M:1F, which is concordant with ratios found elsewhere on Australian coasts for *Spinifex* spp. Kirby (1988) reported an overall fit to 1M:1F for *S. sericeus* in South Australia, and for *S. hirsutus* in Western Australia, but there were some '*S. longifolius*-like' colonies mixed with *S. hirsutus* at three of his sites. In Queensland, McDonald (1983) found 1:1 in *S. sericeus*, and Maze & Whalley (1990a) reported 1M:1F for one beach in New South Wales, but an excess of males on others.

There is general agreement, too, between the sex ratios found in Australia and those in the New World grasses *Buchloe dactyloides* (Schaffner 1920, Quinn & Engel 1986, Wu et al. 1984), *Hesperochloa (Festuca) kingii* (Fox and Harrison 1981), and *Distichlis spicata* (Freeman et al. 1976). *Distichlis distichophylla* is the exception.

There was no evidence of ecological differentiation between sex-forms as reported in *Distichlis spicata* by Freeman et al. (1976), or of a shift in sex ratio with a change in ecological conditions as detected in *Hesperochloa kingii* (Fox & Harrison 1981); ecological conditions were probably too uniform at the sites examined.

The predominance of females in *D. distichophylla* must result from some factor other than the rhizomatous habit. It seems logical to assume that the local distribution reflects vegetative reproduction by fragmentation and water dispersal. This species may have been distributed vegetatively on a much larger scale than our localised samples show, because specimens held in NSW, representing its whole geographic range, are mostly female. There may be, in fact, a series of very large clones. This distribution seems unrelated to female preponderance as discussed by Lloyd (1974).

We have no data of the kind Charnov (1982) would find essential to test sex ratio theory, for example, form of sex ratio control, investment of resources, differential mortality by sex. We do, as Charnov said '...refer to adult sex ratios and question the extent of deviation from equality'; we can do little else. But for *Spinifex sericeus* some results of McDonald (1983) in Queensland and in New South Wales of Maze & Whalley (1990b) are relevant to Charnov's points. In New South Wales among plants raised from seeds (some transplanted into a dune) there were 15M and 15F; in the plants that grew from seeds sown into dunes on South Stradbroke Island, Queensland, the frequency of female inflorescences was 0.41, a little less than the frequency in natural populations.

Reproductive effort in *S. sericeus* (Maze & Whalley 1990b) is also consistent with what Lloyd & Webb (1977) consider to be generally characteristic of dioecious species in: (i) male colonies producing significantly more inflorescences than female colonies; (ii) a preponderance of male inflorescences at the beginning of the flowering season; and

Table 2. Sex-form frequencies in three grasses.

	No. plants		Frequency of females	1:1 X^2	Transect length m	Herbarium collection
	M	F				
Zygochloa paradoxa						
New South Wales Lake Menindee						
(a)	12	12	0.50	0	100	S.J. 5517, 5518, 5519 5520, 5521
(b)	11	28	0.72	7.410	100	
(c)	6	12	0.67	2.0	100	
(d)	10	18	0.64	2.286	100	
Kinchega	27	18	0.40	1.8	250	S.J. 5522, 5523
32°20'S 142°25'E Total	66	88	0.57	3.143		
Spinifex longifolius						
Western Australia Cable Beach 17°56'S 122°12'E	19	20	0.51	0.025	120	S.J. 5833, 5834, 5835
Pseudochaetochloa australiensis						
Western Australia Wyndham; Five Rivers Lookout 15°22'S 128°12'E	31	35	0.53	0.242	50 m x 10 m	S.J. 5547, 5548

Note: Specimens from all populations are in NSW and duplicates at CHR; numbers preceded by S.J. are S.W.L. Jacobs' collecting numbers.

(iii) male inflorescences producing more florets than female inflorescences. Resource investment in maleness ensures a relatively high proportion of male:female gametes early in the season, but this alone does not allow of any estimate of the opportunities for fitness gain.

In *Distichlis* there was no significant difference in the number of florets per spikelet and number of spikelets per inflorescence, and thus no suggestion of initial resource investment at different levels. Because the two sex-forms rarely co-occur and because of their habit, it may be difficult to assess quantities such as the relative number of inflorescences per plant, or relative differences in colony sizes.

Kaplan (1972) and Gregorius (1983) proposed that wind-pollinated, dioecious species maximise the average number of pollinated ovules per plant — optimal pollination efficiency — when females are in excess of males. So far, female frequency is not known to exceed 0.5 in natural populations of dioecious grasses. Either, optimal pollination efficiency is not attained, or their models are inappropriate.

These initial results are insufficient to generate new insight into sex ratio interpretation or of the significance of wind-pollination on fitness, but support the 1M:1F sex ratio, *Distichlis distichophylla* excepted. Sex-form frequency and data on differential reproductive effort measured in Australian dioecious grasses, as begun by Maze & Whalley (op.cit.), will be information of the kind which could advance knowledge of the sex ratio in the grasses, and advance its theoretical base.

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Manusript received 1 February 1990

Manuscript accepted 7 March 1991

Regeneration of complex notophyll vine forest (humid subtropical rainforest) in eastern Australia – a review

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Abstract

Summerbell, Gillian (Hornsby Physiotherapy Centre, P.O. Box 1519, Hornsby, NSW, Australia 2077) 1991. Regeneration of complex notophyll vine forest (humid subtropical rainforest) in eastern Australia. – a review Cunninghamia *2(3): 391–410.* Complex notophyll vine forest (CNVF) has been perceived to be fragile and vulnerable to physical site changes and disturbances. High species richness, evenness of distribution and mixing of species provide diverse plant/animal interactions, balanced herbivore activity and a relatively predictable and constant environment. Regeneration of CNVF occurs in small canopy gaps. Environmental heterogeneity and partitioning of resources allows establishment of mature-phase species. Regeneration management aims at community stability, richness and diversity through manipulating successional pathways and re-establishing small canopy gaps. Each area must be assessed before regeneration techniques are implemented. CNVF areas in eastern Australia require active management for immediate and long-term survival. Few are large enough to be self-maintaining with a full complement of species. Each site should be managed in a regional context, to provide resources for mobile species and to conserve rare, ancient and endangered species. Any logging needs to allow for sustained species richness, diversity and highly interwoven plant/animal interactions. Selective logging based on regrowth of the overstorey or recovery of basal areas to levels similar to unlogged forests, completely ignores the composition of the forest and requirements for the community to reach full maturity. Public education, financial incentives, further research, funding aligned with enacted legislation are all necessary for effective management and conservation.

Introduction

Some 80,000 square kilometres of rainforest were present in Australia before European settlement (Webb & Tracey 1981). Today about one quarter remains.

These rainforests have great biological significance. In Queensland for example thirteen of the nineteen families of primitive angiosperms which evolved on the Gondwana continent some 120 million years ago, are present today (Vandenbeld 1988). The concentration of primitive families in the Australasian region is the greatest in the world (Webb & Tracey 1981). Two-thirds of the plant and animal species found in our rainforests are endemic to Australia (Bell 1981).

Increasing areas of rainforest have been afforded protection under World Heritage status. However, rainforests still face significant natural and man-made threats. Natural ones include fire, disease, landslides and cyclones. Human-induced threats result from tourism, recreational vehicles, introduction of exotic species, clearing for agriculture and commercial resource use (southern Queensland, Victoria and Tasmania). Active management is constrained by lack of financial resources and limited knowledge of rainforest ecology.

Complex notophyll vine forest in Australia

There are four main types of rainforest: tropical, subtropical, warm temperate and cool temperate (Webb & Tracey 1981).

Complex notophyll vine forest (CNVF), the richest form and most complex type of subtropical rainforest (Webb & Tracey 1981), is classified as subtropical vine forest, raingreen and quasi-evergreen in regions of high and seasonal summer rainfall and eutrophic soil status (Webb 1968b 1978, and Hitchcock 1976). It occurs in patches from Mossman in north Queensland to the Illawarra region in NSW, with the major part in the southern Queensland – northern NSW region. The distribution is determined by climate, topography, microclimate, soil, fire and competition. Rainfall is above 1300 mm, and soils tend to be well drained and basalt enriched (Floyd 1989). CNVF may be species rich. A hectare can contain more than 100 different trees, 60 species of vines, 70 ferns and a host of other plant forms (Churchett 1982). Floristic composition may depend not only on the physical environmental factors, but also on the distribution of relict and narrowly endemic species (Barlow & Hyland 1988).

Review of regeneration processes

Disturbance

The forest canopy is a mosaic of gaps, patches of juvenile trees in former gaps and mature forest (Whitmore 1986). The effect of different types of disturbance on rainforest will depend on the disturbance regime within which it has evolved. Disturbance which is unusual to a particular forest type will have a far greater impact than that which falls within the usual disturbance regime (Hopkins 1981).

Large-scale disturbance

This may be due to natural or man-made effects; cyclones, landslips, volcanic activity, tectonic plate movement, flooding, wildfires and logging, especially clear-felling regimes. The size of the disturbance can be from several hectares to several hundred hectares or up to many square kilometres (Webb 1977).

Medium-scale disturbance

This type of disturbance covers an area from 5 square metres to approximately 10 hectares (Webb 1977). Logging, roadways through rainforest, windthrows, local eddies and downdraughts associated with cyclones, local landslips and small fires may cause this scale of disturbance.

Small-scale disturbance or small gaps

This is usually the result of falling branches of a single tree or the death of a single tree.

Regeneration and succession

Succession is the process through which regeneration is achieved. Succession expresses the differences in colonising ability, growth and survival of organisms adapted to a particular set of conditions on an environmental gradient (Smith 1980). The replacement of one of several species or groups of species by others results from interspecific competition and the interaction of herbivores, predators and disease.

The nature of succession in a given area will depend on seed availability, conditions for germination and liberation of suppressed saplings in relation to fortuitous formation of canopy gaps, changes in microclimate and predation (Webb & Tracey 1981). Hopkins et al. (1977) divided the species of humid subtropical rainforest into four major groups, describing their survival strategies and their role in the successional process.

Group A, pioneer species
Short-lived, shade tolerant perennials that grow up to 8 metres high. They begin the regeneration process in areas of medium to large disturbance. Examples are *Rubus rosifolius* and the naturalised *Solanum mauritianum.*

Group B or early secondary species
With environmental modification these predominate and form a closed canopy. They are fast growing perennial trees (10–25 metres high) living for 15–50 years. Examples are *Euodia micrococca* and *Alphitonia excelsa.*

Group C, late secondary and Group D, mature phase species
With a canopy present these are more favoured by the altered conditions. Examples of Group C species are *Brachychiton acerifolium* and *Diploglottis*, while examples of D Group species are *Sloanea woollsii* and *Agyrodendron trifoliolatum*. By 40–50 years of regrowth, almost all the vascular species of the adjacent primary forest are represented in the under-storey. It may take another 40–50 years before the mature or Group D species have reached the fruiting stage. Secondary forests are unlikely to become reproductively independent of the adjacent primary forests until they are approximately 100 years old. This four-stage pathway of regeneration is called the 'facilitation' model (see Figure 1).

The 'tolerance' model allows for any species present before disturbance to be able to colonise the area after the disturbance. This model is commonly used to describe succession in small gaps. Opportunistic species often exploit the changed environment first, but not in every case in this model. They do not provide for more advantageous conditions for later species. Later species will only grow if they can tolerate lesser levels of resources. As in the facilitation model, the successional end point is reached when the most shade tolerant species occupy and retain the site (Smith 1980).

Delayed or arrested succession is described by the 'inhibition' model. Here, early colonists prevent the invasion of subsequent colonists or suppress growth of already existing species. This is often the case when trees and shrubs have few seeds or propagules in the soil (Hopkins et al. 1977). Succession may proceed at a later date if the dominant pioneer species is destroyed or damaged by herbivores, fires, pathogens or herbicides.

Outcomes of the successional process

Restoration of the original community

Following disturbance, secondary succession eventually restores the original community. Webb & Tracey (1981) emphasise that the disturbance must not be too extensive or too frequently repeated, and disturbed areas should be able to maintain patchiness in space and variety of serial stages in time to allow for the total display of all species available. Adequate seed sources of the original community must remain available, either stored in the soil or dispersed from adjacent living plants.

Deflected community

This occurs where partial intermittent destruction is accompanied by environmental changes persistently unfavourable for the return of the original community (Webb & Tracey 1981). Reasons for the inability of the community to regain its previous composition are discussed in the next section on breakdowns in the successional process.

Hybrid community

In hybrid communities destruction is more complete and sustained, so that some environmental changes become permanently unfavourable and seed sources become more limited. The disturbed area is colonised by pioneer species. Gradually with slow changes in local climatic and soil conditions, the original community becomes fragmentary and relict (Webb & Tracey 1981).

New community

Complete destruction of the original community and its seed sources takes place and there are many changes in the physical environment. The site is colonised by a new community depending on the proximity of seed sources of other community types and few of the original species are able to adapt and survive in competition with them.

The process of succession stops (unless delayed or arrested) when the climax stage is reached. This is the point where the community is stable and self-replicating and barring disturbances will persist indefinitely (Smith 1980). Community restoration can take up to 800 years after a widespread disturbance (Hopkins et al. 1977).

Breakdowns in the successional process

Deflected or arrested succession can result from a variety of factors (Hopkins 1981). Physical site factors such as soil compaction, soil porosity, nutritional status of soils, water table levels, can be changed by a disturbance. The pathway of succession may not proceed along facilitation or tolerance lines due to altered conditions.

Biological site factors can modify the secondary successional process in a number of ways:

(a) Lack of later phase species in the seed bank can arrest the process. A good example is the 'Big Scrub' in northern NSW, formerly a vast area of lowland subtropical rainforest extensively cleared for agriculture in the early 1900s. The forest regeneration on many of the abandoned areas now appears to be arrested at an early secondary stage (Hopkins 1981). A disturbance can expose the soil seed bank to high surface temperatures. Experiments by Hopkins & Graham (1984) on heated seeds, showed that at 60°C (a temperature reached in the summer months after about one hour's direct exposure to sunlight), half the seeds were destroyed. At 100°C, all were destroyed.

(b) Succession can be deflected or arrested if an alien species such as *Lantana camara* prevents the establishment of late phase species (see Figure 2).

(c) Geographical barriers can arrest the successional process. Many CNVF species survive in isolated pockets and largely depend on local seed availability. A major disturbance to one of these isolates is likely to arrest succession if viable seed is not available in the region (Hopkins 1981).

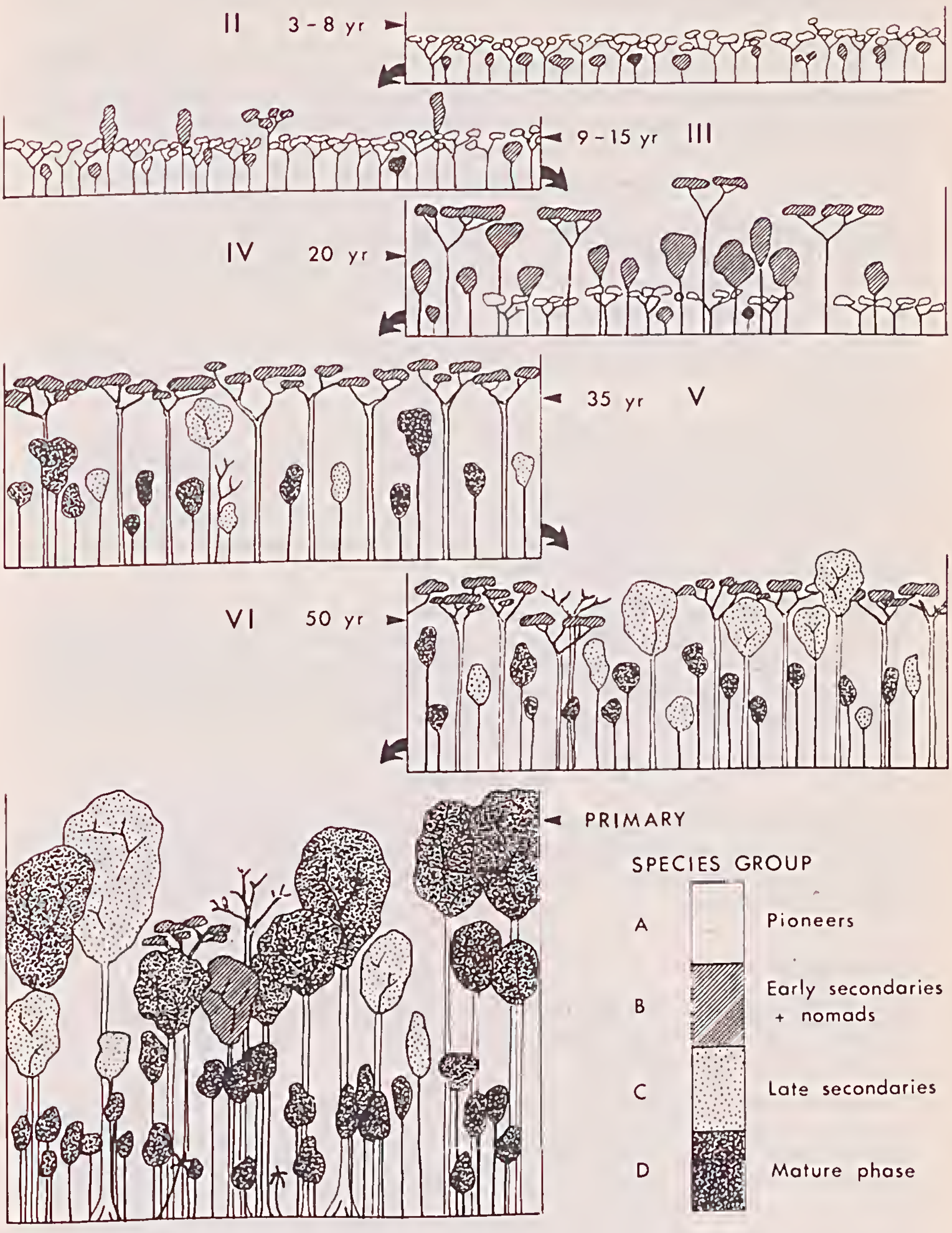

Figure 1. Schematic representation of reconstructive secondary succession in CNVF (from Hopkins 1981) (Equivalent to the Facilitation Model).

(d) Many human activities maintain the continuing occupation of sites by alien or early secondary species. Permanent openings of the forest canopy for roads, tracks and clearings allow these opportunists to occupy higher light areas. Their growth and production of profuse long-lived seeds enable them to quickly spread into other edge areas (Hopkins et al. 1977).

(e) Frequent disturbances in a community can permanently alter the species' composition diversity and hence stability of that system. Cyclone scrubs in the tropical lowland rainforests of northern Queensland are the result of frequent cyclones preventing the re-establishment of mature rainforest (Webb 1958).

Gap-phase dynamics — the gap environment

Gap creation provides an injection of new life into the rainforest community. The characteristics of the mature (D-type) rainforest species appear to have developed from gap creation. Stocker (1983) has developed a gap regeneration theory which states that in most tropical forests the component species must have evolved in relatively small gaps created by canopy disturbance. Large gaps would have been relatively rare or so infrequent that they would have little or no evolutionary significance.

Gap-phase dynamics affect many different forest processes. These include: forest structure, spatial pattern and life history features of germination, growth, time of flowering, seed dispersers and predators, herbivores, pollinators and pathogens (Bazzaz 1986.) Levels of light in the gap area have a major role in partitioning gap resources. Each species is able to achieve optimal growth in different parts of the gap or gaps of different size (Stocker 1988).

According to the size of the gap, various gap filling mechanisms contribute in gap creation. In *very small* gaps there is sapling growth and increased growth of branches of adjacent trees. In *small* gaps advanced regeneration of suppressed medium seedlings, and resprouting. In *large* gaps there is regeneration from seed bank present in the soil. Most seeds are located in the subsoil layers.

Reproduction

Four processes interact to generate the seed 'shadow' that finally produces a seedling 'shadow', namely, seed production, predation, dispersal and dormancy (Janzen & Vazquez-Yanes 1986). There is great variation in these mechanisms from pioneer to mature phase species.

Seed production

Seed production by A and B-type species occurs regularly. Large numbers of well dispersed seeds have long viability and comprise the majority of seeds in the seed bank just below the soil surface.

C or late secondary species fruit most years with seed viability mostly limited to several months, although some species can survive up to two years (Hopkins & Graham 1984). Mature phase or D-type species are characterised by infrequent gregarious flowerings which produce massive quantities of fruit (Hopkins 1975). Seeds are of a short life span, surviving from several weeks to several months. The time interval between these large fruitings is usually greater than three years. In the intervening periods, many individuals sporadically produce smaller quantities of fruit. Such gregarious flowering and fruiting appears to be general amongst rainforest tree species (Wood 1956, Ashton 1969, Medway 1972, in Hopkins 1975). During periods of gregarious fruiting, seed predation can be high.

The soil seed bank, according to Janzen & Vazquez-Yanes (1986), contains representatives of only a tiny fraction of the species of trees in tropical and subtropical forests. The seeds are in haphazard proportions having little to do with any forest structure. Hence dispersal agents are essential links in the establishment of seed shadows.

Seed dispersal

Various agents act as seed dispersers. These include wind, water, gravity, birds, bats and other small mammals. Seed dispersal is an essential process in maintaining forest diversity and regenerating disturbed areas to the original forest structure. Seed dispersal also provides new inputs of genetic material into isolated remnant areas.

The main dispersal agents in subtropical areas are wind, birds and gravity (sometimes assisted by mammals). Water and bats have lesser roles but in particular areas, can be important contributors (Hopkins 1975).

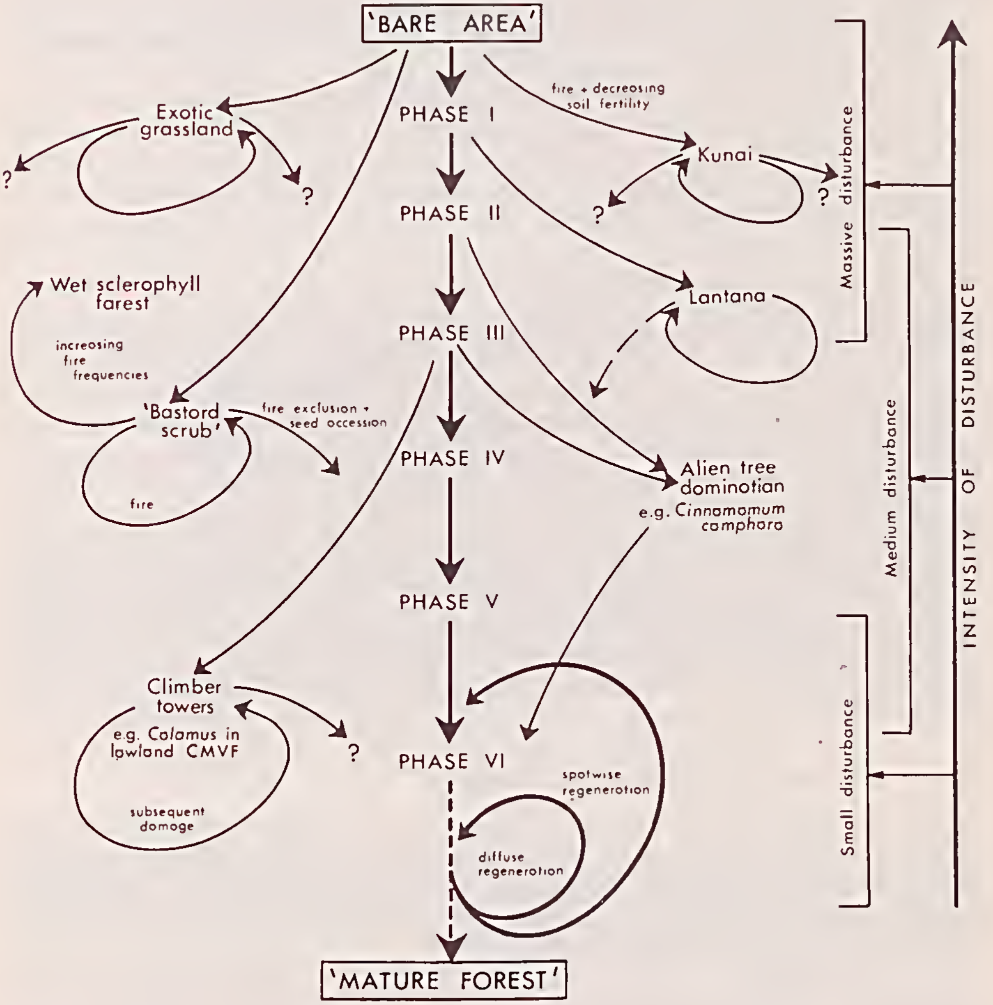

Figure 2. Schematic representation of secondary succession pathway and natural vegetation in rainforest showing some of the variations that can occur in relation to intensity of disturbance (from Hopkins 1981).

Wind-dispersed species are A and B-type species, taller canopy (D-type) species, vines, epiphytes, orchids and ferns. These species have a distinct advantage in medium-large gaps where animal dispersal is diminished.

Birds are attracted to certain colours of fruit. Blue-black and black-red are favoured over red (Floyd 1976). Fruit-eating birds can be divided into opportunists and specialists. Fruits devoured by opportunists are usually small (5–10 mm), many-seeded, often showy and usually juicy. Large fruits attract specialists, and contain few or single seeds. These fruits typify pioneer and climax species respectively (Whitmore 1983). This situation has implications for isolated communities where specialist migratory birds are needed for seed dispersal. Seed dispersal by animals often involves enrichment of the seed by the animal to increase its ability to germinate and also leaching of germination inhibitors.

Seed predation

Seed predation shows no particular pattern. It can vary markedly from year to year, tree to tree and habitat to habitat. Different species have different susceptibilities to different seed predators (Janzen & Vazquez-Yanes 1986). Mammals and insects are the main seed predators in humid subtropical rainforest. Evidence does show that animal predation directly affects the survival and pattern of distribution of seedlings of particular rainforest species (Janzen 1972, Wilson & Janzen 1972, in Hopkins 1975). Hopkins (1975) feels there is little doubt that damage by plant predators and parasites, whether animal, fungi, bacterial or viral, can be a controlling factor affecting the establishment and survival of plants.

Seed dormancy and germination

Seeds of subtropical plants have variable dormancy periods. Germination may occur quickly when the seed is moistened or delayed until the hard seed coat is broken down. Bird ingestion and excretion can accelerate the germination process by several months, as in the case of *Cryptocarya glaucescens* (three months if ingested; six months if not). Many of the short-lived fast growing early secondary species have hard seed coats, which remain buried in the soil for many years (Floyd 1976).

In subtropical rainforests with a definite dry season, seeds may remain dormant if the fruits mature in the dry season. Once the rainy season begins, germination commences (Janzen & Vazquez-Yanes 1986). Stocker (1988) examined the role between fruiting, seed predation and germination in shade-tolerant species. He felt that with the favourable establishment environment for shade-tolerant species and the effects of predation on large seeds of this group, immediate rather than delayed germination has evolved.

Role of pollinators in flowering and fruiting

Plants with a large flower crop tend to be pollinated by large unspecialised pollinators, for example, birds, bats and moths, and tend to flower in synchrony over a short period (Pomeroy & Service 1986). Bawa & Krugman (1986) have suggested that pollinators probably switch from one species to another as the floral resources of one species decline and that of the other increase.

An alternative strategy is to produce a few flowers at a time over a long period, for pollination by specific animal species. These pollinators tend to be birds, butterflies, large moths or large bees (Pomeroy & Service 1986).

Loss of food resources for pollinators or removal of that pollinator from the community may influence pollinator guilds and consequently plant guilds that depend upon these pollinators (Bawa & Krugman 1986). Management strategies require an understanding of pollination modes and the extent to which various plant species are dependent upon particular pollinators. Unfortunately, very little is known about pollination biology in tropical or subtropical forests.

Coppicing

At a subtropical rainforest site in Queensland, 74 of the 82 regenerating species coppiced after felling and burning (Stocker 1981, in Whitmore 1983). The growth of these coppiced species was slower than for trees regenerating from seed. Webb et al. (1972) observed that plants with coppice growth were taller than plants regenerating from seeds at Mount Glorious in southern Queensland and concluded that coppicing conferred a considerable competitive advantage to a plant.

In Lamington National Park in an area regenerating after storm damage, 35 of the 44 tree species present were suckering or sprouting (Olsen & Lamb 1988). Turner (1976) noticed coppicing in some species on steep slopes at Barrington Tops, NSW. He felt the coppicing pattern suggested an element of genetic control, that would enable the better adaptive traits of tree species in the particular environment to be retained.

Rainforest fauna

Birds

Some 90 bird species regularly breed within the rainforests of NSW but only 38 depend on rainforest for the majority of their food or breeding requirements (Morris (1976). Birds may depend on patches of rainforest scattered over thousands of kilometres. Crome (1975) found seven species of fruit pigeons in northern Queensland were nomadic and migratory, with their movements related to tree species and the quantities of fruit available. Competition between species was minimised by this utilisation of different food plants.

Kikkawa (1968) studied the ecological association of bird species in northern NSW and northern Queensland. In northern NSW, the subtropical rainforest areas supported fewer bird species than the dry habitats and he concluded that the avian fauna was impoverished and did not form a unique association with rainforest. By comparison, the rainforests of northern Queensland included a high proportion of 'regular species', where more than half the species utilised this habitat exclusively. Kikkawa (1968) feels that successful colonisation of subtropical rainforest in northern NSW must have been largely limited to those species that had developed or retained adaptions favourable to wet formations in general. Various authors (Gentilli 1949; Keast 1961 and Brereton & Kikkawa 1963, in Kikkawa 1968) have suggested that the poor faunal diversity in rainforest may be explained in terms of past climate and the patterns of speciation and colonisation on the Australian continent.

Mammals

There are no mammals (excluding bats) which exclusively inhabit the CNVF areas of south-eastern Australia. The 41 species of mammals which have been recorded in tropical and sub-tropical areas are only forest generalists and ecotone species (Winter 1988). Absence of specialists is felt to be due to refugia shrinking some 25,000 to 15,000 years ago below the critical size required to maintain a specialist community Bats contribute about one quarter of the total number of mammal species using northern NSW rainforests. Thirty-two species have been recorded, some of which exclusively depend on the rainforest environment (Adam 1987).

Invertebrates

Invertebrates act as seed dispersers, seed predators and pollination vectors. Compared with the vertebrates, many of the rainforest invertebrates are highly specialised in their habitat requirements, being restricted to particular host plant species and in many cases having specific hosts for different stages in their life history (Adam 1987).

Invertebrates as herbivores consume between 10 and 20 per cent of plant material. Young leaves and seedlings appear especially vulnerable (Bazzaz 1986). Injured leaves have been shown to lose more nutrients from leaching than uninjured leaves (Turkey 1970, in Golley 1983). These injured leaves decompose earlier, providing nutrients for special plant requirements such as fruit formation (Golley 1983). Insects, by their defecation systems and short life cycles, also provide a quick release of nutrients for plant usage. Insects can have detrimental effects. Overgrazing can upset the successional process by allowing early successional species to persist under high light levels. Insects cause mortality by providing entry for pathogens and changes in tree structure can arise from loss of plant support tissue (Bazzaz 1986).

Herbivory can vary from site to site due to subtle changes in environmental factors or plant composition. Seasonal variation can be marked as a result of seasonal effects on an invertebrates life cycle or seasonal changes in levels of food supplies (Lowman 1982). Some insects require resources from both mature forests and successional habitats. For example, some aroids and orchids are pollinated by specialist species of euglossine bees, but the bees often require early successional plant species for larval resources (Frankel & Soule 1981). Many tropical pollinators have low population densities, which are susceptible to area effects including the stochastic, demographic and genetic events which are characteristic of small populations (Frankel & Soule 1981). Any reduction in area is likely to result in the extinction of some pollinators and loss of essential catalysts for fertilisation of certain plant species.

Studies on regeneration of humid subtropical rainforest

Studies of the recovery of humid sub-tropical rainforest (CNVF) in Australia have largely been based in the Border Ranges and Lamington national parks area. As this is the largest remaining area of CNVF, one would expect recovery ability to be higher than that of small isolated remnants. Observations at O'Reillys in Lamington National Park on an area cleared and burnt have shown CNVF can recover from a severe man-made disturbance, under certain conditions. Hopkins et al. (1977) describe these conditions as the time since the original clearing, the completeness of the clearing, the effectiveness of the burn and the proximity and type of adjacent forest. Succession started with A-type species and followed along the lines of the facilitation pathway. The developing forest in 1977 was becoming increasingly similar to the adjacent primary forest.

Olsen & Lamb (1988) monitored the recovery of an area of forest near O'Reillys after a heavy storm in September 1983 destroyed the forest canopy, creating a large gap. Some isolated trees remained. A year later, early secondary species were growing along with vines, exotic weed species and shrubs. Two years later, primary forest species were regenerating. Thirty-five of 44 species originally present were growing by sprouting. Possible explanations suggested for the quick regrowth of primary forest species after this disturbance were that:

(a) Propagules of some of the primary forest species were shed from residential trees within the gap, although little seed would have been possible due to substantial crown damage.

(b) Residual trees may have acted as important focal points for fruit-eating birds, accelerating the arrival of new tree seed.

(c) In microclimatic terms a large gap may really be the equivalent of a 'small gap' in a tropical rainforest because of the lower solar angle. In a gap with residual trees, the overall effect of these factors may discriminate against some secondary species. Regeneration in this situation has proceeded along the tolerance pathway.

Predictions by modelling of recovery times for CNVF with different logging regimes have been made in the Wiangaree State Forest (now part of the Border Ranges National Park), an area of 14,000 hectares (Shugart et al. 1980; Horne & Gwalter 1982). Horne & Gwalter (1982) estimated the time of recovery of the overstorey after full utilisation logging — i.e. 70–80 per cent removal of the basal area of overstorey — to be longer than 200 years. With more selective logging, namely 33 per cent removal of the basal area overstorey and 50 per cent canopy retention method, recovery time would be approximately 30–60 years. Presumably, regeneration would take the pathway of the facilitation model with full utilisation logging and the tolerance pathway with selective practices.

The model of Shugart et al. (1980) was used to assess the consequences of the harvest of commercial species from CNVF both in terms of single harvest or a repeated harvest. The model predicted increases in the basal area of a number of species would peak 30–50 years following logging and indicated that CNVF should have the regenerative capacity to sustain a conservative logging program on a 30-year cutting cycle.

Predictions in both these studies have implications for the reproductive biology of primary forest species. If D-type species do not produce fruit until 40–50 years old and are not reproductively independent of adjacent primary forests until approximately 100 years old (Baur 1964, Hopkins et al. 1977), how could these forests continue to regenerate to the original forest composition if they are logged on a 30-year cycle? Over several cycles there would have to be a shift in species composition to the early and late secondary species, altering the stability of the forest, animal-plant interactions and threatening the survival of some species.

Modelling predictions by Horne & Gwalter (1982) tend to favour increases of group C species in their occupation of the canopy over group D species. *Doryphora sassafras* increases from 0–10 per cent and *Cinnamomum oliveri* from 2–10 per cent of the canopy, while *Endiandra sieberi* decreases from 31–18 per cent. The authors have stated that logging may cause some alteration in the relative frequencies of the major overstorey species due to their different growth rates. Hence, after several cutting cycles, few adult group D species would be present.

Managements of isolates

Problems of remnants

Remnants or isolates can be classified into two broad types, artificial and natural, depending on whether the isolation was produced quickly by humans or developed naturally in response to longer term changes in climatic and geomorphological processes that usually involve fire. One would expect the abilities of remnants to adapt and survive the various changes brought about by development would be different. The survival of natural remnants tends to suggest that they have adapted to their isolation (Webb et al. 1985).

Remnants face greater threats to the maintenance of community stability than larger reserves. Remnants have a larger ratio of boundary to core area compared with larger reserves. Boundary areas serve as entry points for more competitive exotic species which can initiate interference patterns and inhibit successional pathways. A remnant's microclimate is influenced by the surrounding vegetation. It is likely to be different to a larger reserve with lower humidity levels and higher temperatures.

Current knowledge of the boundary dynamics between rainforest and other vegetation types is extremely limited. A large number of remnants are adjacent to eucalypt forests. Many of the early successional gap opportunitists have characteristics which can successfully colonise these margins. Fire is one disturbance where these colonisers must have special adaption as it is an uncommon event in rainforests. Regular fires in these marginal areas cause species impoverishment and gradual contraction of the isolate (Webb et al. 1985).

Remnants generally need an incoming supply of seeds for genetic variety, species maintenance and continuing community viability. The size of the remnant, the distance of the remnant from the nearest seed sources and the boundaries across which seed dispersers must travel will determine seed dispersal processes. Seed dispersal has an important role in gap regeneration processes. Gap regeneration allows a community to maintain its species richness and diversity. Any interference to these processes by exotic species and human activities, namely a decrease in isolate size or increase in gap size and gap turnover rates, will favour the regeneration of early successional species over mature phase species (Webb et al. 1985). A loss of certain mature phase species will set in motion loss of animal species, increased herbivory and susceptibility to disease. Raven (1976, in Frankel & Soule 1981) has emphasised the high level of specialisation and interdependence of tropical species and predicts that the loss of a plant species can trigger the demise of between 10 and 30 animal species. Frankel & Soule (1981) labelled species which have widespread roles with plant/animal interactions as 'key' species. Table 1 shows the cause and effect relationships following the extinction of several types of key species. Gilbert (1980), (in Frankel & Soule 1981) has described 'mobile links' and 'keystone mutualists' in the synthesis of tropical plant-insect relationships. A 'mobile link' is an animal that is a significant factor in the persistence of distant plant-herbivore communities. Keystone plants are usually sources of nectar, fruit or pollen and provide critical support to mobile link species. These plants include tree genera such as *Ficus*, epiphytes, and early successional plants such as *Solanum* and *Passiflora*. Many keystone plants require early successional habitats or gaps.

For survival of animal species, the situation is quite intricate. Soule (1982, in Webb 1987) and other zoologists consider 500 individuals as a safe minimum level for breeding adults, but there are stipulations and complications due to genetic factors and the effects of logging. Thus, species collapse from inappropriate gap dynamics and unwanted edge effects is perhaps the greatest biological threat to the maintenance of community stability in remnant areas.

The management objectives for a CNVF area are:

1. *A stable community* by manipulation of successional processes (if necessary).

2. *Restoration of the canopy* if it is degraded or disturbed *aligned with the use of canopy gaps.* Where a medium-large disturbance has produced a large canopy opening, reduction to small canopy gaps by the establishment of early secondary species will provide the appropriate environment for the germination and growth of shade tolerant mature phase species. Canopy gaps will need assessment of understorey and soil status and possibly subsequent treatment to provide for environmental heterogeneity.

3. *Restoration of the lower canopy, forest floor and edge areas.*

4. *Identification of key species* of the particular community and additional plantings (if necessary) within their regeneration and habitat niche.

5. When a stable community has developed, *different levels of successional change* are required for resources for animal species and continuing community diversity.

(Webb et al. 1985, Stockard et al. 1985, Hynes 1983, Frankel & Soule 1981)

The processes by which these management objectives will be obtained are:

Thorough assessment of the area
- natural disturbance
- successional pathway stages
- interference
- exotic species
- rare and endangered species
- key plant and animal species
- human disturbance
- incompatible activities

Planning and implementation of management plans
- local objectives
- priorities for action
- techniques of regeneration
- management of incompatible and human activities

Monitoring and research
- assess regeneration techniques
- changes in objectives/priorities/techniques?

Coordination between government agencies and agencies involved in the regeneration process

(Godfrey et al. 1988, Hopkins et al. 1977, Hopkins & Saunders 1987)

The techniques used will be many and varied as each CNVF area is slightly different in community structure, levels of degradation, physical site characteristics and historical evolution. An explanation of techniques used is given in Table 2.

Constraints to management

Constraints to management are just as much a threat to the future of these rainforests as their small size and geographical isolation. Inscribing these areas in NSW on the World Heritage List does not ensure their continued survival without adequate management. Management needs to be bound to some form of enacted legislation to provide funding for assessment, management practices, research and monitoring. At present there is no effective endangered species and community legislation in NSW.

Constraints to management are:

Funding — Rainforest management should be intensive and ongoing. The Federal Government has allocated over $20 million for a National Rainforest Conservation program (Department of Arts, Heritage & Environment 1987), whether funding for regeneration of degraded areas has been included, is unknown to the author. Funding must also come through endangered habitat legislation, as previously mentioned.

Data on synecological and autecological aspects of humid subtropical rainforest are quite limited — This must restrict the potential effectiveness of management. The importance of increased research and monitoring cannot be overemphasised.

Table 1. Some possible cause and effect relationships following the extinction of four kinds of key species, with particular emphasis on tropical forests (Frankel & Soule 1981).

Ecological category	**Cause of local extinction**	**Effects of extinctions on diversity**	**Indirect effects**
I. Large predators	area effects increases	herbivore density increases	habitat destruction from overbrowsing, compaction, grazing, trampling and predation
	hunting	competitive excusion among prey species	extinction of ground nesters, plants
II. Large herbivores	area effects	extinction of large predators	the *Indirect effects* in row III
	hunting	loss of early successional habitats	
III. Generalized key species (e.g. bees, butterflies, bats and birds)	area effects	reproductive failure from reduced pollination and seed dispersal in low density plants lacking specialized mutualists	extinction of plants
	loss of early successional habitats		extinction of specialized herbivores
			extinction of specialized parasitoids and predators
			destabilization of coevolved food webs
IV. Certain critical plants	commercial collecting or selective cutting	starvation and emigration of generalist pollinators	*Indirect effects* in row III
	loss of early successional habitats		

Lack of public awareness of the fragility of rainforest environments — Human disturbances to small areas can be just as, if not more damaging, than a natural disturbance. Human disturbances can be of an ongoing nature which may not permit the regeneration process to reach beyond the pioneer stage. Management plans must consider all present and future human threats and incorporate appropriate actions to eradicate or minimise these destructive influences.

Few trained personnel with expertise in rainforest management — Many of the CNVF areas have only recently come under the protection of World Heritage status, hence management of these areas is in its infancy and few have had time to experience this field of reserve management.

Lack of communication — Co-ordination between multiple government agencies could retard the efficacy of management and conservation of rare and endangered species.

Discussion

The richness and complexity of CNVF is bound in the biotic elements of the community. The vegetation holds the majority of the nutrients within its living tissue, the plant species diversity provides a vast range of resources for animals and a buffer to the overexploitation by herbivores, predators and pathogens. The large variety of animals in turn acts as a catalyst in essential plant reproductive strategies to maintain species diversity.

The type of disturbance and its effects on the physical environment will determine the recovery process. Hopkins (1975) mentions that where the disturbance is artificially maintained by roads and clearings, the ability to regenerate is threatened. The physical effects of machinery may provide inappropriate establishment conditions (Webb et al. 1972). Where a massive disturbance occurs the final composition of the vegetation would also be expected to be determined by the floristic composition of the adjacent forest. This has obvious implications for remnants where the adjacent forest is unlikely to be CNVF.

Considering stability and specialised interrelationships of subtropical species, what reserve sizes will be necessary to preserve all species of CNVF? This question is difficult to answer due to lack of information on rainforest species populations and ecosystems. Ashton (1976, in Webb 1987) considered that 200 mature individuals was the minimum effective population size for rainforest trees. In 1000 hectares of forest (for the complex forests of Borneo), 60 per cent of the species should be left intact and in 2000 hectares, all but the rarest species would be likely to be conserved. Webb (1987) suggests that 'even undisturbed reserves (that is, not too drastically disturbed by people who inhabit all of the surrounding areas) may already be too small to be self-sustaining in the longer term, i.e. on time scales reckoned by centuries. Besides adverse social pressures, biological factors include loss of essential fauna for pollination and seed dispersal, a slow run-down in genetic fitness, and population sizes that are already too small to prevent species extinction.'

Hopkins (1975) feels that substantially larger areas of rainforest are needed to retain 'stability' than are necessary in more simple vegetation types. He predicts that any restriction on this 'habitat species area' could lead to gradual simplification of the community. Many reserves are too small to always contain all the necessary successional stages for the persistence of some herbivore species (Frankel & Soule 1981). The role of key species needs more identification and research. The fact that these species can have a profound role means that management should clearly be preserving and monitoring their activities.

Community education about the fragility of rainforests is needed to assist the preservation of remnants of CNVF. The misuse of Wingham Brush until fairly recently is an example of the little understanding the general public have of rainforest complexity and stability. Community service groups, local media, lectures in schools and interpretative signs on site are useful ways of providing this information.

The general public are not the only ones ignorant of conservation. Mills (1987) expresses much concern at the lack of appreciation of rainforest conservation by government. Pressure on the remnant vegetation of the Illawarra Region increases weekly, not uncommonly emanating from the activities of government departments. The development of service corridors, coal mines and their associated waste disposal dumps and urban expansion have taken their toll in recent years.

Table 2. Aims and techniques for the restoration of degraded CNVF sites (Floyd 1984, Stockard et al. 1985 & Kooyman 1988).

Forest	Causes of degradation	Techniques for restoration
Canopy	vine overgrowth	mechanical and chemical means (Glyphosphate, e.g. Roundup) – follow up treatment at periodic intervals; initial canopy vine treatments should be undertaken in the non-growing season.
	large canopy gaps from disturbance	suitable fast growing A & B Group species; or use of clump plantings – a mixture of AB & CD Group species with shrubs and palms and A & B type species in between clumps. Clump plantings provide quicker re-establishment of the rainforest environment, structure and pattern of species distribution. Use of local species where possible.
Rainforest edge	vine overgrowth; exotic species	mechanical and chemical means; treatment here is more successful after the main canopy has been treated, otherwise light conditions will allow edge species especially exotics to enter the rainforest body.
Lower canopy and forest floor	vine overgrowth; exotic species	mechanical and chemical means after the overhead canopy is intact and weed-free for 2-3 years.
Incompatible trees, e.g. *Cinnamonum camphora*	promote fire, out-compete native species	mechanical/chemical means.
Steep slopes	exotic species	where use of machinery is restricted or it is unsuitable to clear the whole site, contour line clearing is used; clump planting re-establishes a canopy and shades light demanding exotics; ongoing maintenance required.
Exposed sites	high velocity winds	windbreaks to protect seedling trees; examples include *Pittosporum undulatum* and *Acacia melanoxylon.*
Frost-prone sites	frost affecting growth of C & D Group species	nurse crop of A & B Group species such as *Macaranga tanarius* and *Commersonia bartramia*.
Grassed areas		mechanical and chemical means to remove grass; begin spraying 2 weeks prior to planting and follow up spraying for around 3-4 years; use of newspaper and bagasse mulch will markedly reduce the need to continue spraying.
Cleared lands with remnant trees	agricultural pursuits	fencing to exclude stock; single and multiple clump plantings with a great mix of species and suitable edge species; palms and shrubs can be planted in between clumps

Multiple commercial use of tropical forests may be economically desirable but, in practice, slowly simplifies the community. Logging in humid subtropical rainforests, currently only being practised in Queensland, clearly needs more monitoring and research to justify the 30 to 60-year logging cycles, advocated by Shugart et al. (1980) and Horne & Gwalter (1982). All of the studies undertaken have described a shift in species from mature phase to late secondary ones with logging in this time-frame. With the current knowledge on CNVF, harvesting every 30–60 years cannot be described as sustainable forest management.

Baur (1964) described rainforest trees as having great variations in diameter growth in individual trees of similar age and species and advocated more emphasis be placed on plantation establishment. He stated that species are known to be capable of producing mature trees in half the time or less from plantations. However monoculture plantations have not been successful to date. Webb (1968a) reported that *Grevillea robusta* (a non-gregarious tree species) 'checked' after about 10 years. Seedlings of *G. robusta* did not persist in these plantations due to intraspecific competition from the adult species. Other species have been susceptible to insect attacks, fungi, pathogens etc. Stocker has described the most useful tropical rainforest species as those possessing a high degree of shade tolerance and suggests growth at high light levels is inversely related to their shade tolerance. Hence, the scope for greatly increasing the productivity of tropical rain-forests by silvicultural modification is limited. Stocker (1983) advocates growing large gap-type species in plantation environments.

Further research is of paramount importance if future management is to intimately understand the dynamics and floristic patters of the CNVF environment and be able to predict the effects of management practices. Research must largely be based in situ rather than in the laboratory, as Webb (1968a) has illustrated. What happens in an artificial situation is quite different to normal community interactions.

The importance of protecting all areas of humid subtropical rainforest cannot be overstated. Government agencies with control of CNVF areas have to become more aware of their uniqueness, fragility and need for active management. Placing an area under a reserve or national park status without specialised management will not guarantee the stability and viability of this area in the future. Assessments need to be undertaken of each area and plans of management developed.

A system of managed reserves requires conservation agreements with private landholders. These agreements appear most successful where economic incentives are available through tax write-off and rate relief schemes. With only 3 per cent of CNVF in private lands in NSW, it would not be an expensive measure to be able to protect the remaining endangered species.

For management plans to be implemented, they need to be bound to legislation such as the Victorian Flora and Fauna Guarantee Act, 1988 to obtain appropriate funding. This Act provides a strong legislative basis for the conservation of threatened species in Victoria by listing all threatened species and communities, preparing policy statements on each species and community and then preparing management plans for all listed species. At present, there is no similar legislation in NSW, although, the National Parks and Wildlife Service is preparing a discussion paper on projected legislation (Kennedy 1989). One hopes a similar decisive act will be introduced in NSW.

Acknowledgments

I would like to thank Dr L. Webb for his generous assistance with references, Drs D. Goldney and A. Gillison for their time in critically analysing this paper and Dr J. Stockard for the opportunity to discuss management of degraded areas. Sincere thanks also to Nick Stepkovitch for his support and patience and to Linda Raper for typing this document.

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Manuscript received 15 July 1990

Manuscript accepted 19 April 1991

Vegetation on rocky outcrops and ranges in central and south-western New South Wales

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Abstract

Norris, E.H. & Thomas, J. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia 2000) 1991. Vegetation on rocky outcrops and ranges in central and south-western New South Wales.* Cunninghamia *2(3): 411–441.* The natural vegetation of rocky outcrops and ranges in the Lake Cargelligo, Griffith and Berrigan district (33°19'S 146°22'E to 35°40'S 145°49'E) is described (Central Western Slopes, South Western Slopes and South Western Plains botanical subdivisions). Nineteen sites were sampled on different geological types: sandstone, granite, slate and rhyolite. Vegetation in general is eucalypt woodland with a mixed shrubby to herbaceous understorey. Plant communities relate to geological type. A list of 338 species (283 native, 55 exotic) is provided. Isolation of the vegetation as a result of clearing for agriculture, and the disturbance of many of these sites by feral animals, grazing and quarrying are important factors to consider for future conservation and management.

Introduction

Low ranges and isolated rocky outcrops representing the boundary between outcropping Palaeozoic bedrock and the Tertiary/Quaternary alluvial plains flank the eastern edge of the South Western Plains of New South Wales. Being less accessible and having generally poorer soils, these outcrops often retain the only natural vegetation in a landscape substantially modified by agricultural use. Some are conserved as National Parks or Nature Reserves, whilst others, such as Mount Galore, are under the control of local Shire Councils. Others are subject to varying degrees of grazing and other land use.

Little information is available on the vegetation of these outcrops, especially the smaller ones (NSW National Parks & Wildlife Service, Forestry Commission of NSW and the Soil Conservation Service of NSW pers. comm.). This study examines rocky outcrops and ranges between the towns of Lake Cargelligo in the north and Corowa in the south (300 km apart), and between Ardlethan in the east and Jerilderie to the west (110 km apart) (Figure 1). These include the Cocoparra, Lachlan and McPhersons Ranges, Boat Hill and Mount Boomanoomana. Also included were the Keginni Range north of Roto, and Manfred Range south of Darnick. An initial account of the vegetation of these rocky areas and their potential conservation significance is provided.

Geology and soils

The rocky outcrops within the study area comprise Palaeozoic geosynclinal sediments within the Lachlan Geosyncline, a marine trough forming part of the Central and Southern Highland Fold Belt (Packham 1969; Butler et al. 1973)). Part of the Lachlan Geosyncline is characterized by a wide belt of Ordovician sedimentary and

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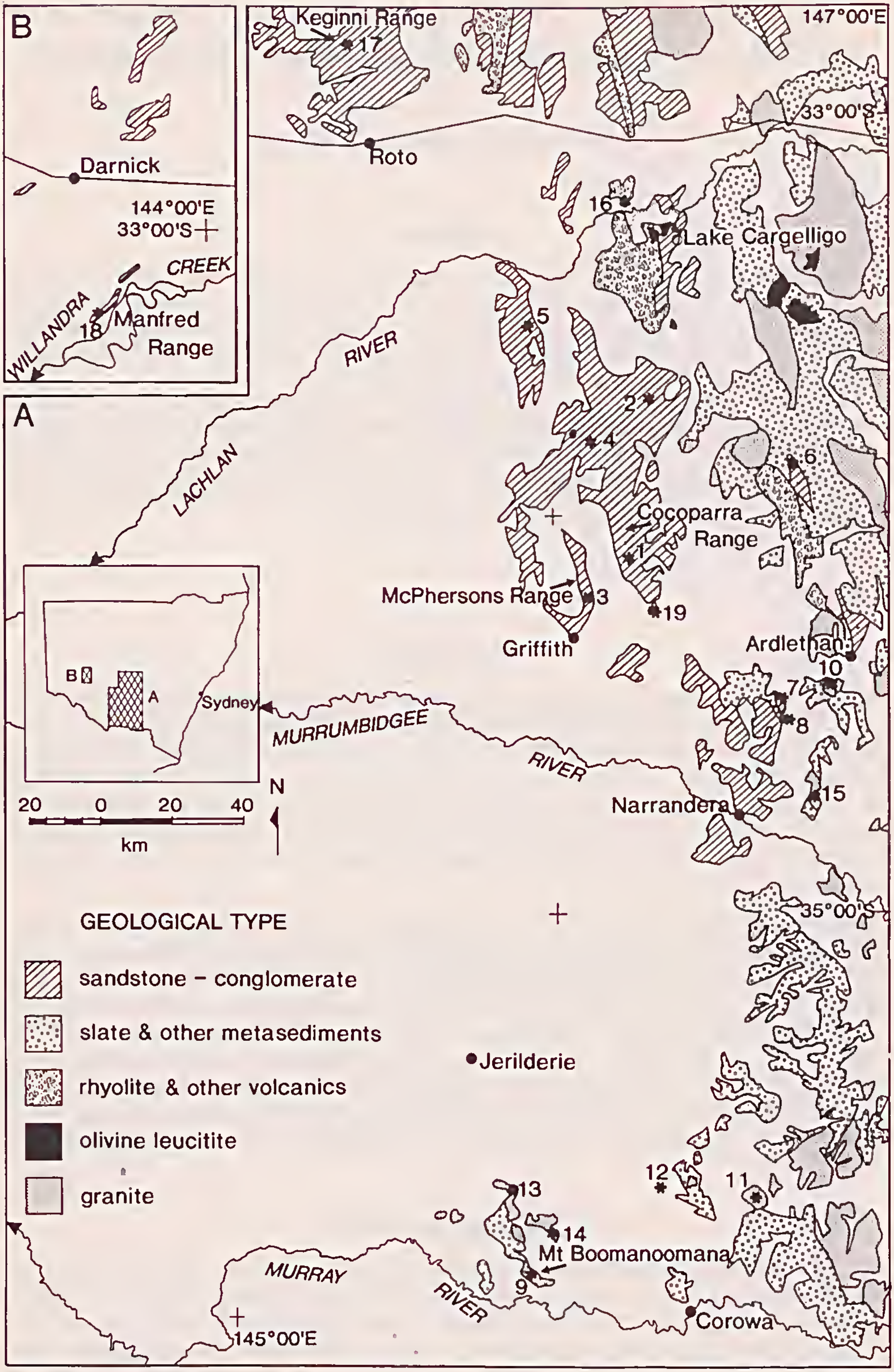

Figure 1. Map showing the study area and the main geological types (modified from Geological Survey of New South Wales (1972)). Numbers refer to sites. Major towns and rivers are also shown.

metamorphic rocks and granite masses (the Wagga Metamorphic Belt), with the western flank comprising a large area of Upper Devonian quartz sandstones of the Cocoparra Group. Some minor occurrences of possible Silurian sediments and volcanics can be found within its boundaries (Packham 1969). Hills north and west of Lake Cargelligo are formed on quartz-feldspar porphyries and rhyolites. Sandstones of the Mulga Downs Group outcrop in the northern and western section of the study area and include the Keginni and Manfred Ranges respectively (Geological Survey of New South Wales various dates 1971, 1968) (Figure 1, Table 1).

Skeletal soils or lithosols occur where rock is near the surface. These comprise shallow sands, loams and clay loams and are always stony or gravelly due to the presence of fragmented rock material showing some degree of weathering. (Stace et al 1968). Sandstone lithosols are found at sites in the Manfred, Keginni and Cocoparra Ranges, at Mount Bunganbil, Mount Wammera and sections of Jimberoo Creek State Forest.

Deeper soils derived from sandstones, mapped as massive, neutral red earths (Soil Conservation Service 1986), occur on slopes in Cocoparra National Park, the Lachlan and McPhersons Ranges and Jimberoo Creek State Forest . These soils are mainly sandy in texture, red-brown to brown in colour with a weak profile differentiation gradually increasing in clay content with depth (Stace et al 1968).

Surface weathering of granite usually produces a shallow sandy loam. Such soils can be found at sites including Berrigan, Grong Grong and parts of Mount Goombargana. Granite-derived soils at sites influenced by slope tend to have a contrasting profile with the A-horizon being a loamy sand to sandy loam 20–30 mm thick overlying a very sandy clay. Such profiles occur at several sites including Mount Goombargana, Bald Hill Tank and The Boat Hill.

Geomorphology

The landscape is characterised by depositional sand and flood plains surrounded by a margin of low relief erosional landforms rising 30 to 300 m above the adjacent plains (Palfreyman 1984). Erosion has resulted in valley incision with narrow alluvial valleys within the ranges and bands of alluvial and colluvial material around the footslopes. The long continued action of streams is evident by the depth of alluvium accumulated on the plains to the west (Butler et al 1973).

Vegetation

Prior to European settlement, the vegetation of the region was a mosaic of open-forest, mallee and *Acacia pendula* shrublands on the plains country, whilst the outcrops and ranges carried forests and woodlands. Allan Cunningham (1817) collected species from these outcrops and ranges including *Hibbertia, Goodenia, Grevillea* and *Prostanthera* from Mount Narriah and the Cocoparra Range.

Cambage (1901) recorded species between Mount Hope and Parkes, Beadle (1948) described the *Eucalyptus dealbata – E. sideroxylon* Association (using the name *E. dealbata* for what we now know as *E. dwyeri*) occurring on some of these rocky outcrops with notes on soils and erosion, and Moore (1953) described vegetation alliances of the south-eastern Riverina, listing species and discussing the relationships between vegetation and environmental factors. There are also species lists for prominent outcrops and ranges such as The Rock, Mount Galore and Cocoparra National Park and Nature Reserve (Willis 1967; Logan 1974; National Parks & Wildlife Service no date; Bladen no date; Burrows 1989). Cunningham et al (1981) include habit and habitat details for species recorded from these rocky outcrops and ranges. The Con-

Table 1. Site number, locality, map sheet and grid reference (1:250 000 topographic sheet); elevation (m) and area (ha), geology and field observations for sites recorded in this survey.

Site no.	Locality map sheet grid ref.	Elevation (m) area (ha)	Geology	Field observations
1	Mt Bingar NARRANDERA GR 424785	455 m >1000 ha	Late Devonian Cocoparra Group: pebbly sandstone with thin conglomerate bands, sandstone and lithic sandstone	sandstone; shallow brown sandy loam, c. 10cm deep; stones on surface
2	Jimberoo Ck State Forest CARGELLIGO GR 427837	c.300 m >1000 ha	Cocoparra Group: sandstone and siltstone, orthoquartzitic sandstone	sandstone; slope area - dark sandy skeletal material, well drained ridge area - brown loamy sand, shallow and stony, many boulders
3	McPhersons Range NARRANDERA GR 409778	254 m >1000 ha	as for Site 1	sandstone; soils generally thin; clayey on footslopes & small benches
4	Flagstaff Hill CARGELLIGO GR 410824	380 m >1000 ha	as for Site 1	sandstone; hard compacted reddish clay
5	Lachlan Range CARGELLIGO GR 397855	c. 340 m >1000 ha	as for Site 1	no field data
6	Mt Narriah CARGELLIGO GR 472816	486 m c. 500 ha	as for Site 2	sandstone, abundant outcrops; soils skeletal sandy in parts; more clayey in bench & saddle areas
7	Mt Bunganbil NARRANDERA GR 467743	c. 300 m c. 700 ha	Cocoparra Group: conglomerate, pebbly sandstone, sandstone & siltstone, lithic sandstone	sandstone; shallow loamy well drained soils; deeper soils on benches; summit & eastern aspect with sandy skeletal soil and large exposed bedrock areas
8	Mt Wammera NARRANDERA GR 471734	331 m 200 ha	as for Site 7	sandstone & pebbly sandstone; footslopes - damp shallow clayey sand; westerly bench - shallow sandy soils, deep in parts with higher clay content

Site No.	Locality map sheet grid ref.	Elevation (m) area (ha)	Geology	Field observations
9	Mt Booman-oomana JERILDERIE GR 390567	255 m c. 600 ha	Ordovician low grade metasediments: slates, phyllites, quartzose greywacke	metasediments; shallow sandy soils with many stone fragments on the surface in more exposed areas
10	Bald Hill Tank NARRANDERA GR 483745	284 m <100 ha	Middle Silurian Ardlethan Granite: porphyritic muscovite-biotite granite	granite; coarse sandy granitic soil, shallow in parts over exposed bedrock; seepage areas on lower slopes.
11	Mt Goombargana JERILDERIE GR 459591	403 m c. 600 ha	Jindera Granite: biotite granite	granite; coarse granitic sandy soils
12	Quarry JERLIDERIE GR 439596	250 m c. 200 ha	as for Site 11	as for Site 11
13	Berrigan JERILDERIE GR 383592	120 m <100 ha	Berrigan Granite: coarse biotite granite	as for Site 11
14	The Boat Hill JERILDERIE GR 397582	182 m <100 ha	as for Site 13	as for Site 11
15	Grong Grong NARRANDERA GR 478712	189 m <100 ha	Grong Grong Granite: medium-grained muscovite-biotite granite	granite; loamy sand
16	Mt Rossi CARGELLIGO GR 421881	380 m >1000 ha	Silurian (?) Ural volcanics: rhyolite, rhyolite breccia, quartz-feldspar porphyry, chert and tuff	geology not confirmed; dark sandy loam
17	Keginni Range IVANHOE GR 336943	c.150 m >1000 ha	Late Devonian Mulga Downs Group: quartzite and sandstone, pebbly to conglomeratic in part, siltstone and shale.	sandstone; soils not investigated
18	Manfred Range POONCARIE GR 748323	176 m c.1000 ha	as for Site 17	no field data
19	Mt Binya NARRANDERA GR 429774	224 m >1000 ha	as for Site 17	sandstone; soils not investigated

dobolin, Cobar and Hay District Technical Manuals (Soil Conservation Service 1974, 1978, 1986) include information on vegetation, geology and soils for outcrops occurring within their districts and the Forestry Commission (1984) describes vegetation types on ranges within the the Griffith Forestry District.

Climate

The region is semi-arid and displays a rainfall and reliability gradient from east to west. Stations at Jerilderie, Narrandera, Griffith and Lake Cargelligo receive an average annual rainfall between 380–420 mm. Keginni Range receives approximately 330 mm whilst Manfred Range in the west receives 263 mm (Bureau of Meteorology 1991). Over the long term rainfall is generally winter dominant although there have been periods when a summer rainfall influence has extended to the NSW–Victorian border (Cunningham et al 1981).

Average temperatures for the area range from the 30 and 35°C for summer maxima with summer minima between 14 and 18°C. Winter maxima are between 13 and 16°C with winter minima between 3 and 5° C (Bureau of Meteorology 1991).

History and land use

Several Aboriginal tribes occupied the region. To the east the Wiradjuri inhabited the plains and waterways such as the Lachlan River, with their territory extending east to the Western Slopes. The Barkindji occupied country east of the Darling River including the Manara Hills, Manfred Range and the Willandra Lakes system (Allen 1979/1980; Central Mapping Authority 1987).

John Oxley explored the area in 1817. On arriving at the base of Mount Narriah (Site 6) he wrote 'The country having been recently burnt, some good grass was found for the horses a little to the south west' (Oxley 1820). On many occasions he makes reference to the presence of Aboriginal people in the region commenting on their behaviour and use of fire. 'Three or four fires were seen in the north west, and recent traces of the natives were discovered near our tents'.

Squatters moved stock into the area from the late 1830s. Land along the river systems was taken up first, and by 1848 there were a number of runs established (Soil Conservation Service 1974). Cattle at first predominated but were later replaced by sheep (Cunningham et al 1981). Wheat had been sown by 1866 and became the major agricultural product at the end of the nineteenth century (Forestry Commission 1984). Mining has occurred particularly north of Lake Cargelligo where copper mining began in the late 1860s; copper and gold mining were reported at the turn of the century between Mount Tinda and Condobolin (Cambage 1901). Granite outcrops to the south of the study area have been quarried for road and railway construction material.

Clearing of the best agricultural lands between about 1880 and 1910 left islands of vegetation on the more infertile and/or inaccessable outcrops and ranges. State Forests were declared over remnant forest and woodlands in the early twentieth century and many are associated with the range system and include the Lachlan and Melbergen Ranges, the Naradhan Range and associated Jimberoo Creek area. Apart from the economic value of the timber the state forests are used for recreation, education, apiary and grazing (Forestry Commission 1984).

Methods

Potentially rocky areas were identified from the 1:250 000 geological maps, Cargelligo, Narrandera, Jerilderie, Ivanhoe (Geological Survey of New South Wales various dates) and the 1:500 000 Wentworth sheet (1971). The presence of natural vegetation and the isolation and accessibilty of these rocky areas were determined from photomosaics (New South Wales Department of Lands 1:50 000 Photomap Series).

Field inspection of a representative range of rocky outcrops was carried out. Four major geological types were sampled; sandstones (Cocoparra Group, Mulga Downs Group), granite (Ardlethan Granite, Jindera Granite, Berrigan Granite, Grong Grong Granite), rhyolite (Ural Volcanics) and slate (low grade metamorphics). The term 'geological type' is used in a generic rather than specific sense as the sites comprise various rock strata. For most sites geology was confirmed in the field (Table 1). Many promising geological areas were seen on the photomosaics to be heavily disturbed and were not visited. This was particularly so for areas of low relief in the south on Ordovician sediments and Silurian granites. Other potential sites deemed worthy of sampling were visited but not sampled because of their obvious clearing of the understorey for pasture; for example, Mount Arthur (NARRANADERA 487694), Mullemblah Hill (JERILDERIE 476059) and Blue Hill (JERILDERIE 489067).

The vegetation of each outcrop was recorded from 20 x 20 m quadrats and traverses. To cover the full range of habitat diversity, quadrats were located on different topographic positions to sample variations in aspect and slope. Up to three quadrats were recorded at a site depending on area and disturbance. In each quadrat floristic composition (both native and exotic), structure (tree height and number of strata) and species abundance (with an abundance scale of frequent, common, occasional and rare) were recorded. In highly disturbed areas with little variation, species were recorded along traverses with brief notes on structure. Most of the data were collected during October 1986 (Sites 2–16). Data from Site 1 was collected in June 1989, Site 17 in June 1988, Site 18 in October 1983, and Site 19 in October 1989.

TWINSPAN (two-way indicator species analysis) (Gauch 1982) was used to group Sites 2-16 according to similarities in species composition. Sites 2–16 were used for the numerical analysis as the data were collected at the same time minimising seasonal variation. A total of 248 species comprised the data set. Ordination of the species across sites using the program DECORANA (detrended correspondence analysis and reciprocal averaging) (Gauch 1982) was used as an aid to determine the potential effects of environmental gradients.

Results and discussion

From the nineteen sites and four geological types (sandstone, granite, slate and rhyolite) 338 species were recorded (Appendix) representing 67 families, the dominant being Asteraceae (54 species) and Poaceae (44 species). A total of 25 species were trees, 56 species were shrubs and 257 were ground species. 55 exotic species were recorded, 17 from the Poaceae.

Geological influence

Moore (1953) reported little correlation between vegetation and geological type, explaining that some vegetation alliances develop equally well on soils derived from differing substrates and similar substrates of differing geological ages. In considering dominant tree species this study showed general agreement with Moore (Table 2).

Table 2. General vegetation recorded at each site.

1 Mt Bingar

Low open-woodland: *Callitris endlicheri* and *Eucalyptus sideroxylon*. Mixed shrubby understorey dominated by *Melaleuca erubescens, Grevillea floribunda* and *Calytrix tetragona*.

2 Jimberoo Creek State Forest

Lower slopes dominated by a low open-woodland of *Eucalyptus macrorhyncha, E. dwyeri* and *Callitris glaucophylla*. *E. dwyeri* and *Acacia doratoxylon* on ridges. Understorey comprising regenerating shrubs after recent fire (1985).

3 McPhersons Range

Low open-woodland: *Eucalyptus populnea, E. dwyeri* and *Acacia doratoxylon*. Dense patches of *Allocasuarina verticillata* amongst Acacia *doratoxylon*. Open grassy understorey .

4 Flagstaff Hill

Low open-forest: *Callitris endlicheri*, occasional *Eucalyptus dwyeri* and *Acacia doratoxylon*. Herbaceous understorey. *Eucalyptus sideroxylon* frequent on slopes with the understorey dominated by dense *C. endlicheri* regeneration.

5 Lachlan Range

Lower slopes a low open-woodland of *Eucalyptus dwyeri* and *Callitris glaucophylla* with a herbaceous understorey (grazed). Steep slopes dominated by a shrubland of *Beyeria viscosa* amongst boulders. Summit dominated by *Acacia doratoxylon*, understorey herbaceous to shrubby (grazed).

6 Mt Narriah

Low open-woodland: *Eucalyptus dwyeri, Acacia doratoxylon* and *Callitris glaucophylla*. Shrubby understorey dominated by *Grevillea floribunda, Teucrium corymbosum, Pandorea pandorana* and *Gonocarpus elatus*. Scattered *Eucalyptus sideroxylon* and *Prostanthera ovalifolia*.

7 Mt Bunganbil

Slopes have a low open-woodland dominated by *Eucalyptus dwyeri, Acacia doratoxylon* and *Callitris glaucophylla* with a shrubby understorey of *Grevillea floribunda, Cassinia laevis, Prostanthera nivea, Calytrix tetragona* and *Pandorea pandorana*. *Stypandra glauca* and *Helichrysum semipapposum* common. Summit dominated by *E. dwyeri, A. doratoxylon* and *Allocasuarina verticillata*, with *S. glauca, C. tetragona* and thickets of *Platysace lanceolata*.

8 Mt Wammera

Slopes dominated by *Eucalyptus dwyeri, Acacia doratoxylon* and *Callitris glaucophylla*. Herbaceous understorey comprising *Gonocarpus elatus, Stypandra glauca* and various grasses. Ridge areas dominated by *E. dwyeri, A. doratoxylon* and *Allocasuarina verticillata* with *Stypandra glauca* and *Platysace lanceolata* and scattered *Prostanthera nivea* and *Calytrix tetragona*.

9 Mt Boomanoomana

Open-woodland: *Eucalyptus microcarpa* and *Callitris glaucophylla*, understorey predominantly grasses with occasional shrubs. *Allocasuarina verticillata* common on stony areas. Dense regrowth of *C. glaucophylla* (4–5 m) on the southern aspect.

10 Bald Hill Tank

Low open-woodland: *Eucalyptus dwyeri* and *Acacia doratoxylon*, herbaceous understorey dominated by *Arctotheca calendula, Cheilanthes austrotenuifolia* plus various grasses and forbs.

11 Mt Goombargana

Eucalyptus dwyeri low open-woodland on slopes and summit with occasional *Acacia doratoxylon*. *Allocasuarina verticillata* locally common on flat rock shelves, and small pockets of *Eucalyptus albens* occur below the summit. The herbaceous understorey is dominated by *Gonocarpus elatus, Geranium* species, *Erodium botrys, Stypandra glauca, Vulpia bromoides* and *Bromus rubens*.

12 Quarry

Low open-woodland: *Eucalyptus dwyeri* over a herbaceous understorey dominated by grasses and introduced species.

13 Berrigan
Herbaceous stratum only.

14 The Boat Hill
Low open-woodland: *Eucalyptus melliodora*, *Callitris glaucophylla*, *Crassula* species, *Erodium* species, various grasses and introduced herbs.

15 Grong Grong
Occasional *Eucalyptus dwyeri*, *E. populnea* and *Callitris glaucophylla*. Herbaceous understorey.

16 Mt Rossi
Low open-woodland: *Eucalyptus dwyeri* and *Callitris glaucophylla* on the lower slopes with a herbaceous understorey, massive regrowth of young pine. Midslope dominated by *E. dwyeri*, *Acacia doratoxylon* with occasional *Eremophila longifolia*. Summit carries *E. dwyeri* and *Allocasuarina verticillata* with *Prostanthera nivea*, *Gonocarpus elatus* and occasional *Microseris lanceolata*.

17 Keginni Range
Low open-woodland: *Eucalyptus intertexta*, *Callitris glaucophylla* with scattered *Acacia aneura* and *A. doratoxylon*. Understorey shrubby to herbaceous (grazing) with *Acacia decora* and *Cheilanthes austrotenuifolia*.

18 Manfred Range
Open-shrubland: *Acacia brachystachya*. *Callitris glaucophylla* on escarpment amongst outcropping bedrock, scattered shrubs including *Dodonaea* species. Understorey herbaceous with abundant grasses.

19 Mt Binya
Woodland of *Callitris endlicheri* and *Eucalyptus crebra*. Mixed shrubby understorey with many regenerating *Callitris* species and *Dodonaea* species.

Generally, the lower slopes of outcrops and outcrops of low relief (for example Manfred Range, 176 m) contained the same species as the surrounding country, for example *Callitris glaucophylla*. Outcrops of higher relief (usually greater than 200 m) generally had a low open-woodland structure with two species predominating,*Eucalyptus dwyeri* (68% of sites) and *Acacia doratoxylon* (74% of sites). These two species occurred in a range of habitats at each site and on different geological types.

Tree species did not appear to be influenced by rock type but showed more variation with regard to altitude, soil depth and type and position on slope. *Callitris glaucophylla* commonly occurred especially on the footslopes and on benches where there was greater soil development. *Eucalyptus sideroxylon* occurs sporadically on loamy soils on the footslopes of the larger ranges in the north of the survey area where it often forms extensive stands and dominated the vegetation, for example, in the Lachlan Range State Forest. Low open-forest dominated by *Callitris endlicheri* occurred over the high ridges on stony soils such as in the Lachlan Range.

In contrast the understorey showed strong relations with geological type. On sandstones the understorey comprised a dense to open shrub strata and a varying cover of herbs and grasses (Table 3). On granite and slate sites the understorey was dominated by grasses and herbs, with shrub species almost completely absent. Mount Rossi (Site 16) on rhyolite had some areas dominated by grasses and herbs but other areas having a prominent shrubby component.

Of the total species recorded, the sandstone sites (with 53 species/site) are significantly richer than the granite sites (with 30 species/site) ($t=3.44$, d.f.=11, $p<0.05$), having a large number of shrubby and herbaceous species (Tables 3 & 4). As only one site each was sampled for the slate and rhyolite lithology no comparison of richness has been made.

Table 3. Total number of trees, shrubs and ground species, and total number of species recorded for the four geological types. Figures in brackets denote number of species confined to individual geology (* denotes one site sampled only).

Geological type	No. trees	No. shrubs	No. ground species	Total
sandstone	18 (11)	49 (41)	189 (118)	256 (170)
granite	10 (2)	4 (-)	96 (40)	110 (42)
slate*	5 (-)	4 (4)	39 (11)	48 (15)
rhyolite*	7 (2)	8 (3)	49 (8)	64 (13)

The number of species restricted to each geological type varied considerably; 66% were confined to sandstone, 38% to granite, 31% to slate and 20% to rhyolite (Table 3).

Numerical classification

Classification and ordination using TWINSPAN and DECORANA for sites 2–16 confirmed differences in the vegetation between the sandstone and granite lithologies (Figure 2). Generally all sandstone sites are grouped together, as are most of the granite sites. For the sandstone sites there appears to be an east-west geographic separation, i.e. the western sites, (3,4,5), are separate from the more easterly sites (2,6,7,8). Climatically, the western sites are slightly drier, and lithologically, the western sites are more similar to each other when compared with the eastern sandstone sites. The granite sites display a north-south geographic separation, probably reflecting factors such as climatic and geological differences. Exceptions to these general trends are Mount Boomanoomana (Site 9), Bald Hill Tank (Site 10) and Mount Rossi (Site 16). Without more detailed field sampling the interpretation of these results is open to speculation.

Significant species

Several rare plants were recorded. *Phebalium obcordatum* (Rutaceae) (coded 3RCa by Briggs & Leigh 1988) was recorded on the summit of Mount Bingar in Cocoparra National Park and Mount Binya in Binya State Forest at the southern end of the Cocoparra Range. It is also known from Yathong Nature Reserve.

Pomaderris cocoparrana (Rhamnaceae) is a newly described species originally included, but distinct from, the widespread species *P. andromedifolia* (Walsh 1990). It has been recorded for Mount Binya (this survey) and Cocoparra National Park. It has been assessed as 2RCat (Walsh 1990).

Although not recorded for this survey *Acacia curranii* (Fabaceae - Mimosoideae) occurs in the vicinity of Shephards Hill north of the study area. This is lithologically similar to Mount Rossi in the Ural Ranges (Site 16) and the species may occur on more inaccessible areas of the ranges further to the south. This species is coded 3V (Briggs & Leigh 1988) as its population is considered vulnerable and is not reserved.

Fifteen species recorded (12 native, 3 introduced) represented extensions of range for the South Western Slopes and South Western Plains (Appendix). Six were recorded for Jimberoo Creek State Forest (Site 2), burnt by wildfire 10 months previous, and includes the unusual occurrence of *Xanthorrhoea glauca* subsp. *angustifolia* (Xanthorrhoeaceae) which has a scattered distribution and is usually found on rocky (lime-

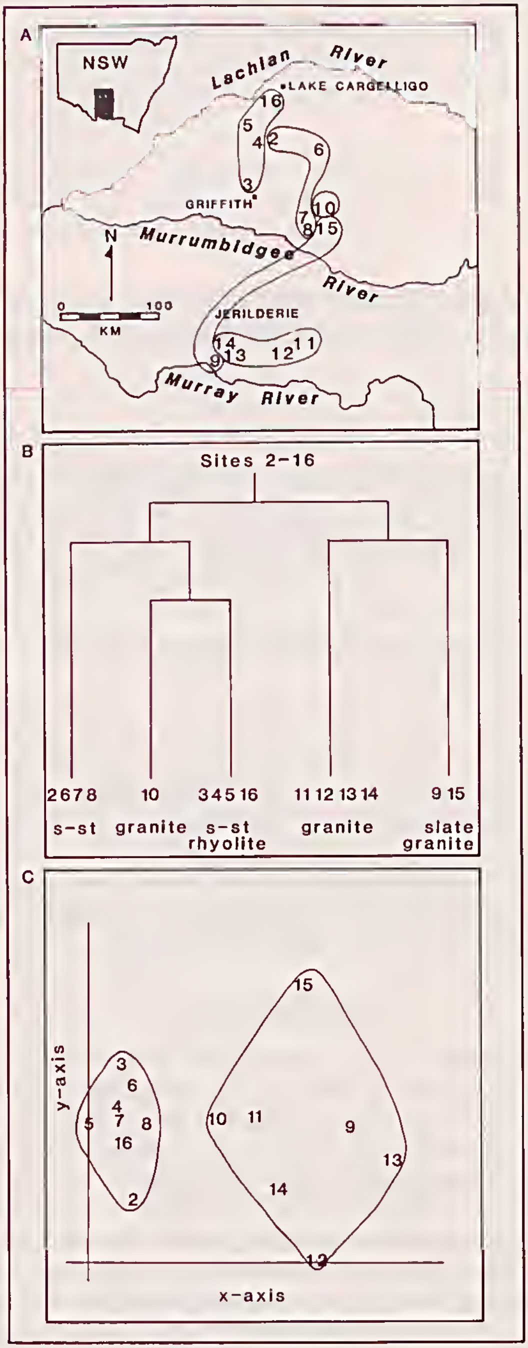

Figure 2. TWINSPAN classification (a & b) and DECORANA ordination (c) for sites 2–16.

Table 4. Geological type, number of sites, mean number of species/site and percentage of introduced species.

Geological type	No. sites	Mean no. species	Mean no. intro. spp.	% introduced species
sandstone sites	11	53 ± 5.09	7	13%
granite sites	6	30 ± 3.8	11	37%
slate site	1	44	9	20%
rhyolite site	1	63	5	8%

stone and trachyte) and gravelly slopes on the Dividing Range further east (Bedford 1988). Jacobs & Lapinpuro (1986) record this species as X. *australis* subsp. *australis* 'western form'.

Disturbance

Most of these rocky outcrops and ranges have been disturbed to varying degrees. Granite outcrops of low relief have been the most affected. Many have been quarried for railway construction, most have active rabbit populations, and some are grazed by sheep. These sites have significantly higher numbers of exotic species (37%) compared with the sandstone sites (13%) ($t=2.59$, d.f.= 11, $p < 0.05$) (Table 4). The sandstone vegetation contains fewer exotic species and disturbance generally is from logging and browsing by goats.

Introduced species

Of the 338 species recorded for this survey 55 (17%) are introduced. Many are species from adjacent agricultural lands. All sites had some exotic species. This infestation ranged from 3 (Site 4) to 14 (Site 14) introduced species. Seven common weed species occur on three of the four geological types, these being *Arctotheca calendula, Hypochoeris glabra* (Asteraceae), *Echium plantagineum* (Boraginaceae), *Aira cupaniana, Briza minor, Bromus rubens* and *Vulpia myuros* (Poaceae).

Feral animals

The predominant feral animal of the outcrops and ranges is the goat (*Capra hirsus*). These are highly selective feeders selecting the most nutritious parts of the plants such as leaves, buds and fruits (Downing & Mitchell 1988). They show a marked preference for browsing small trees and shrubs, but eat grasses and other herbs during drier times (Breckwoldt 1983). Their diet includes a wide selection of native species and some introduced species. Goats are capable of pulling down branches and will readily climb into bushes, destroying them. Obvious damage in Cocoparra Range includes the breaking down of *Acacia deanei* and *Goodia medicaginea* and the browsing of *Callitris endlicheri* and *Maytenus cunninghamii* (Brickhill pers. comm.). Goats are present in moderate numbers in the Keginni Range (Site 17) and in the Cocoparra Range; they were also recorded for Flagstaff Hill (Site 4), Lachlan Range (Site 5), Mount Bunganbil (Site 7), Mount Goombargana (Site 11) and Manfred Range (Site 18).

Rabbits (*Oryctolagus cuniculus*) were noted on sites where the soils are deeper and topography less rugged, particularly on granites in the south including The Boat Hill (Site 14) and also on the McPherson and Manfred Ranges (Site 3 and 18 respectively). Friable soils to a depth of 75 cm or more are favourable for warren construction (Parer & Libke 1985). First introduced to Australia in the late 1850s, they have multiplied and spread throughout much of southern Australia, becoming the most damaging pest in the country (Breckwoldt 1983). Although population numbers were greatly reduced by the introduction of myxomatosis during the 1950s, population numbers are again on the increase.

Rabbits can physically damage shrubs and trees through direct grazing and ringbarking, and overgrazing of both herbs and shrubs together with the effects of burrowing can lead to severe erosion and habitat destruction.

Fire

Only one site, Jimberoo Creek State Forest (Site 2), showed evidence of a recent fire (1985) which was both crown scorch and combustion particularly on the ridge areas (Jolly pers. comm.). Mount Goombargana (Site 11) has carried a wildfire some years previously (Packer pers. comm.) as have areas of the Cocoparra Range. Other large range areas would be expected to carry fire at some time. On many of the smaller outcrops there did not appear to be any evidence of fire. This may be a result of their small area, isolation and/or the open nature of the vegetation. Alterations to the natural fire regimes result from fragmentation through land clearing (Hobbs 1987) and management (forestry, mining and reserves).

Conservation and management

Major conservation reserves in the south western slopes and plains relevant to this study include Yathong Nature Reserve (NR), Nombinnie NR, Mount Bootheragandra NR, Cocoparra NR and National Park, The Rock NR and Mount Galore. Most of these reserves are on sandstone lithology. Plant communities occurring on granite and rhyolite geological types are not represented in any reserves and many are privately owned.

Representative vegetation communities on granite lithology are worthy of protection. The smaller, more isolated granite outcrops in the south of the study area are heavily disturbed. Continued disturbance, isolation and the resulting lack of corridors for species dispersal and reproductive success suggests that these small isolated outcrops will continue to degenerate (Hobbs 1971). Protection of larger areas are necessary if long-term viability is to be maintained.

Control of introduced animals, weed invasion, land use and to a certain degree, fire, are management concerns for conservation areas.

Other rocky outcrops

As a reconnaissance survey it has not been possible to visit all rocky outcrops in the south west and further work on additional sites needs to be done. The significance of the slate and rhyolite sites (9 and 16) requires further sampling. Vegetation on the Manara Hills and Darnick Ranges in the west of the study area is of interest to compare with Keginni and Manfred Ranges (Sites 17 and 18 respectively). Other areas of interest are the olivine leucitite outcrops, a Tertiary alkali basalt, at Mount Melbergen in the Melbergen Ranges west of Rankins Springs, and areas west of Lake Cargelligo.

Conclusion

This study has shown the significance of the vegetation on the outcrops and ranges. The vegetation is characteristic for geological type particularly for sandstone and granite. Although having some tree species in common, sandstones sites are richer in understorey species and have a large shrub component. In contrast granite sites have fewer species most of which are herbaceous.

Of the four geological types, all have species restricted to individual geologies (between 20% and 66%). Many of these outcrops and ranges represent islands of native vegetation amongst extensive tracts of agricultural land and conservation on a variety of vegetation and geological types should be undertaken.

Acknowledgments

The authors would like to thank Doug Benson, Marilyn Fox, Judy Scott, Jocelyn Howell and Marianne Porteners (National Herbarium), Peter Mitchell (Macquarie University) and Dominic Sivertsen (National Parks & Wildlife Service) for advice and criticism on the manuscript. John Brickhill, John Benson (NPWS) and Bob Chalmers (Forestry Commission of NSW) for information, maps and access to some of the areas surveyed. For advice on soil and geological matters we thank Peter Mitchell and Dick Flood (Macquarie University). For assistance with field work we thank Marilyn Fox, Gwen Harden and Penny Farrant (National Herbarium). Thanks also to Bob Coveny and staff of the National Herbarium for identifying plant specimens. For access to private property we thank Arthur Jolly 'Statheilan' via Rankins Springs and Carmel Packer 'Goombargana' via Walbundrie.

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APPENDIX

Species recorded from sites on rocky outcrops and ranges in south-western NSW (q = quadrat; t = traverse).

Site:

1 Mt Bingar, Cocoparra National Park (qt)
2 Jimberoo Creek State Forest (qt)
3 McPhersons Range (t)
4 Flagstaff Hill, Lachlan Range State Forest (q)
5 Lachlan Range (qt)
6 Mt Narriah (qt)
7 Mt Bunganbil (qt)
8 Mt Wammera (qt)
17 Keginni Range (t)
18 Manfred Range (t)
19 Mt Binya, Binya State Forest (qt)

9 Mt Boomanoomana (t)

10 Bald Hill Tank (t)
11 Mt Goombargana (qt)
12 Quarry N of Corowa (t)
13 Berrigan (t)
14 The Boat Hill (t)
15 Grong Grong (t)

16 Mt Rossi (qt)

* introduced species
# new record for New South Wales
! extension of known range in New South Wales
? query on identification

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
PTERIDOPHYTES																			
Adiantaceae																			
Cheilanthes austrotenuifolia	1	2	3	4	5	6	7	8	17	18	19	9	10	11					16
C. distans							7			18	19								
C. sieberi subsp. *sieberi*	1									18	19								
Pleurosorus rutifolius	1		3		5	6	7		17	18	19								
P. subglandulosus														11					
GYMNOSPERMS																			
Cupressaceae																			
Callitris endlicheri	1	2				6		8											
C. glaucophylla	1	2				6	7	8		18		9	10						16
ANGIOSPERMS																			
Amaranthaceae																			
Ptilotus atriplicifolius subsp. *atriplicifolius*					5														
P. gaudichaudii var. *parviflorus*										18									
P. nobilis										18									
P. polystachyus										18									
P. spathulatus																			16
Anthericaceae																			
Arthropodium minus	1		3									9							
Thysanotus patersonii		2	3			6		8				9	10	11					16
Tricoryne elatior	1																		
Apiaceae																			
Daucus glochidiatus	1	2	3	4	5	6	7	8				9					14		16

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
!Hydrocotyle callicarpa								8											
H. laxiflora	1																		
Platysace lanceolata	1	2		4		6	7	8											
Trachymene cyanopetala			3				7	8											
T. ornata					5														16
Apocynaceae																			
Parsonsia eucalyptophylla			3			6	7			18	19								16
Asphodelaceae																			
Bulbine bulbosa					5								10						
B. semibarbata		2	3	4	5		7	8		18	19		10						16
Asteraceae																			
Actinobole uliginosum		2	3	4	5	6		8					10				14	15	16
**Arctotheca calendula*		2	3			6	7	8				9	10	11	12	13	14	15	
**Bidens pilosa*					5		7												
Brachycome ciliaris																			
subsp. *ciliaris*										18									
subsp. *lanuginosa*										18									
B. ciliocarpa						6													
B. diversifolia								8											
B. perpusilla var. *tenella*								8											
Calotis cuneifolia	1	2			5				17		19								
C. hispidula			3						17										
Cassinia arcuata												9							
C. laevis	1	2	3		5	6	7	8											16
!C. uncata		2																	
**Centaurea melitensis*										18									
!Ceratogyne obionoides				4															
Chrysocoryne pusilla										18									
Chthonocephalus pseudevax				4	5														16
**Conyza albida*	1																		
**C. bonariensis*		2																	
Cotula australis															12				
Craspedia sp. *O*										18									

	Sandstone											**Slate**	**Granite**						**Rhyolite**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Gnaphalium sphaericum		2								18									
Helichrysum ambiguum										18									
H. apiculatum	1									18	19		10					15	16
H. bracteatum		2	3																
H. semipapposum	1						7												
H. viscosum		2	3			6	7	8			19			11					16
Helipterum demissum				4															
H. diffusum					5		7			18									16
H. jessenii			3				7												
H. moschatum										18									
H. polygalifolium										18									
H. pygmaeum			3							18									
**Hypochoeris glabra*	1	2	3	4	5	6	7	8		18		9		11	12		14	15	
**H. radicata*		2					7												
Isoetopis graminifolia			3																16
Microseris lanceolata																			16
Millotia myosotidifolia			3	4	5	6	7	8		18									16
Minuria leptophylla			3															15	16
Myriocephalus rhizocephalus																13			
**Onopordum acanthium*																	14		
Podolepis arachnoidea				4															
Pseudognaphalium luteo-album												9							
Senecio anethifolius					5														16
S. quadridentatus	1	2				6	7	8						11			14		
Sigesbeckia australiensis										18									
S. orientalis									17										
**Sonchus oleraceus*	1				5	6	7	8											16
Stuartina hamata										18									
S. muelleri	1	2	3	4	5	6	7	8	17				10	11	12	13	14		16
Triptilodiscus pygmaeus		2		4	5		7	8			19		10	11			14		16
Vittadinia condyloides										18									
V. dissecta var. *hirta*											19								
V. gracilis												9						15	
Bignoniaceae																			
Pandorea pandorana			3		5	6	7												16

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Boraginaceae																			
Cynoglossum australe										18									
**Echium plantagineum*			3									9	10				14	15	
!Myosotis australis		2																	
**Plagiobothrys canescens*														11	12		14		
Brassicaceae																			
Geococcus pusillus									17										
Harmsiodoxa blennodioides	1				5														16
Lepidium papillosum					5														
Pachymitus cardaminoides		2	3																
Brunoniaceae																			
Brunonia australis											19								
Campanulaceae																			
Wahlenbergia communis										18									
W. gracilenta		2	3				7			18									
W. luteola													10						
W. stricta		2	3			6	7	8			19	9							16
Caryophyllaceae																			
**Cerastium glomeratum*		2																	
**Petrorhagia nanteuilii*											19								
**P. velutina*														11	12		14		
**Silene gallica*					5				17		19								
**S. nocturna*			3								19								
**Stellaria media*									17										
Cassythaceae																			
Cassytha melantha	1																		
Casuarinaceae																			
Allocasuarina verticillata		2		4		6	7	8				9		11					16
Casuarina pauper										18									

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Chenopodiaceae																			
Atriplex semibaccata												9?							
Chenopodium desertorum																			
subsp. *anidiophyllum*																		15	
subsp. *microphyllum*								8											
**C. murale*									17	18									
Einadia hastata												9?							
E. nutans	1		3								19						14	15	
Maireana enchylaenoides																13			
M. humillima																			16?
Sclerolaena birchii								8											
S. convexula										18									
Convolvulaceae																			
Convolvulus erubescens																			16
Crassulaceae																			
Crassula colorata																			
var. *acuminata*	1														12		14		16
C. decumbens																			
var. *decumbens*													10		12			15	
C. sieberiana		2								18									
Cyperaceae																			
Carex inversa												9							
Fimbristylis dichotoma	1								17										
!Isolepis marginata		2																	
Lepidosperma laterale s.l.								8				9							
Dilleniaceae																			
Hibbertia obtusifolia	1	2				6													
H. riparia								8											
H. sericea	1	2																	
Droseraceae																			
Drosera glanduligera												9							

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Drosera peltata	1	2											10					15	
D. sp.																	14		
Epacridaceae																			
Astroloma humifusum	1																		
Melichrus urceolatus	1							8											
Euphorbiaceae																			
Beyeria viscosa					5														
Chamaesyce drummondii s.l.	1									18									
Phyllanthus fuernrohrii									17	18									
P. hirtellus form b	1																		
P. hirtellus		2					7	8											
Fabaceae-Caesalpinoideae																			
Senna artemisioides																			
nothosubsp. *artemisioides*											19								16
subsp. *filifolia*											19							15	
Fabaceae-Faboideae																			
Daviesia mimosoides subsp. *virgata*												9							
D. ulicifolia							7												
Dillwynia sericea												9							
Goodia medicaginea		2																	
Glycine canescens	1																		16
G. sp.					5														
Hardenbergia violacea	1																		
Indigofera australis	1		3			6	7	8			19		10	11			14		16
Lotus cruentus											19								
Medicago laciniata									17										
M. sp.	1																		
Mirbelia pungens							7												
Swainsona procumbens															12				
Swainsona oroboides subsp. *sericea*		2																	

	Sandstone											**Slate**	**Granite**						**Rhyolite**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
**Trifolium arvense*											19				12	13			16
**T. subterraneum*												9			12				
**T. tomentosum*											19								
Fabaceae-Mimosoideae																			
Acacia acinacea												9							
A. amblygona		2																	
A. aneura									17										
A. brachystachya										18									
A. burkittii										18									
A. deanei subsp. *deanei*								8									14		
subsp. *paucijuga*	1										19								
A. decora											19							15	
A. doratoxylon	1		3	4	5	6	7	8	17		19		10	11			14	15	16
A. implexa																	14		
A. ligulata										18									
A. paradoxa	1	2																	
A. pycnantha												9							
Fumariaceae																			
**Fumaria bastardii*														11					
**F. capreolata*															12				
**F. densiflora*													10						
**F. muralis*														11					
Geraniaceae																			
**Erodium botrys*												9							
E. cicutarium														11			14		
E. crinitum														11		13	14		
**E. moschatum*															12				
Geranium retrorsum													10				14		
G. solanderi																			
var. *solanderi*		2												11	12				
G. sp.	1																		

	Sandstone											**Slate**	**Granite**						**Rhyolite**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Goodeniaceae																			
Dampiera lanceolata																			
var. *lanceolata*	1	2		4				8			19								16
Goodenia fascicularis			3																
G. glabra	1										19								
G. heteromera			3																
G. ovata	1																		
!*G. stephensonii*																			16
!*Velleia arguta*					5														
V. paradoxa																		15	
Haloragaceae																			
Gonocarpus elatus	1	2	3	4	5	6	7	8	17	18	19	9	10	11			14	15	16
!*Myriophyllum simulans*																13			
Hypoxidaceae																			
Hypoxis glabella														11					
Iridaceae																			
**Romulea rosea*																			
var. *australis*												9						15	
#**Sparaxis pillansii*																		15	
Juncaceae																			
Juncus subsecundus												9					14		
J. sp.		2																	
!*Luzula flaccida*																	14		
L. meridionalis														11					
Lamiaceae																			
Ajuga australis		2			5									11					16
Prostanthera nivea			3				7	8			19								16
P. ovalifolia				4		6	7												
P. striatiflora										18									
Teucrium corymbosum						6													

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Lobeliaceae																			
Isotoma axillaris								8	17					11					
Loganiaceae																			
Mitrasacme paradoxa							7												
Lomandraceae																			
Lomandra multiflora			3			6	7					9						15	
L. patens	1										19								
L. sp.								8											
Malvaceae																			
Abutilon sp.					5														
Sida calyxhymenia			3		5														16
S. filiformis	1									18									
S. petrophila											19								
Myoporaceae																			
Eremophila longifolia																			16
E. mitchellii					5														
E. sturtii										18									
Myrtaceae																			
Calytrix tetragona	1	2		4		6	7	8											
Eucalyptus albens														11					
E. dwyeri	1	2	3	4	5	6	7	8					10	11	12			15	16
E. vicina									17										
E. intertexta									17	18									
E. macrorhyncha	1	2																	
E. melliodora																	14		
E. microcarpa												9		11?					
E. morrisii									17										
E. populnea subsp. *bimbil*			3										10					15	
E. sideroxylon	1					6													
E. viridis																			16

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Leptospermum divaricatum	1	2									19								
Melaleuca erubescens	1					6													
Orchidaceae																			
Caladenia carnea				4			7	8									14		
C. dilatata		2	3																
Calochilus robertsonii		2						8											
Diuris maculata						6		8											16
Glossodia major							7	8											
Pterostylis biseta								8?											
P. mutica			3	4			7												16
P. nana	1																		
P. sp.	1						7					9							
Oxalidaceae																			
Oxalis corniculata		2	3	4	5		7	8											
O. perennans												9							
**O. pes-caprae*														11				15	
O. radicosa	1													11	12				
O. sp.																			
Papaveraceae																			
**Papaver aculeatum*		2																	
Phormiaceae																			
Dianella sp.	1					6												15	
Stypandra glauca	1	2					7	8					10	11					
Pittosporaceae																			
Bursaria spinosa																			16
Pittosporum phillyreoides																			16
Plantaginaceae																			
Plantago drummondii										18									
P. turrifera										18									

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Poaceae																			
!**Aira caryophyllea*		2									19								
**A. cupaniana*							7	8				9?		11		13	14		16
**A. sp.*		2	3	4	5	6		8					10						16
**Alopecurus geniculatus*																13			
Aristida behriana	1																		
A. jerichoensis																			
subsp. *jerichoensis*	1																		
subsp. *subspinulifera*													10						
A. sp.									17										
**Avena barbata*																		15	
**Briza maxima*																		15	
**B. minor*		2										9					14	15	
Bromus arenarius					5					18									
**B. diandrus*																	14		
**B. hordeaceus*													10?				14		
**B. rubens*		2			5	6	7	8		18			10	11	12	13	14	15	16
Danthonia caespitosa		2					7	8?			19	9							16
D. eriantha				4?				8											
D. setacea											19								
Digitaria brownii	1									18									
Elymus scabrus													10						16
**Hordeum leporinum*		2													12				
Eragrostis dielsii										18									
E. lacunaria									17										
**Lamarckia aurea*			3		5		7	8	17	18									
**Lolium perenne*																		15	
**Lophochloa pumila*										18									
Monachather paradoxa										18									
Neurachne munroi			3				7												
!**Periballia minuta*												9							
Poa annua															12				
P. labillardieri								8											
P. sieberiana																			
subsp. *sieberiana*								8				9							
Stipa acrociliata	1																		

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Stipa blackii										18									
S. densiflora											19	9							
S. mollis			3		5	6	7	8						11					
S. nitida										18									
S. nodosa										18		9	10		12		14		
S. scabra subsp. *scabra*	1											9							
subsp. *falcata*		2	3	4		6								11				15	
S. setacea			3											11					
Thyridolepis mitchelliana	1		3	4	5	6			17	18	19								16
**Vulpia bromoides*				4		6							10	11		13			
**V. myuros*		2	3		5		7	8		18	19		10		12		14		16
Polygonaceae																			
**Polygonum arenastrum*																13			
Rumex brownii											19				12?				
R. dumosus																	14		16
Portulacaceae																			
Calandrinia calyptrata																	14		
C. eremaea										18		9					14		
C. sp.	1								17										
Proteaceae																			
Grevillea floribunda	1	2				6	7	8											
Hakea tephrosperma			3		5														
Ranunculaceae																			
Ranunculus lappaceus		2																	
R. pentandrus																			
var *platycarpus*																			16
R. sessiliflorus																			
var. *sessiliflorus*		2						8		18							14		
var. *pilulifer*													10						

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Rhamnaceae																			
Cryptandra amara																			
var. *floribunda*	1																		
Pomaderris cocoparrana	1																		
Rosaceae																			
Aphanes australiana																			16
Rubiaceae																			
**Galium aparine*										18									
G. gaudichaudii					5		7	8				9							
**G. murale*															12		14		
Rutaceae																			
Correa glabra						6													
Eriostemon difformis																			
subsp. *difformis*																			16
E. linearis									17	18									
E. myoporoides																			
subsp. *acutus*		2	3	4			7												
Geijera parviflora										18									
Phebalium obcordatum	1										19								
Zieria cytisoides							7												
Santalaceae																			
Exocarpos cupressiformis	1	2				6	7	8				9							
Sapindaceae																			
Alectryon oleifolius																			
subsp. *canescens*											18								
Dodonaea boroniifolia											19								
D. viscosa																			
subsp. *cuneata/angustissima/ spatulata*	1					6		8											
subsp. *spatulata*								8											

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Scrophulariaceae																			
Limosella curdieana																13			
**Parentucellia latifolia*												9				13	14		
Veronica plebeia												9							
Solanaceae																			
Cyphanthera albicans subsp. *tomentosa*							7												
Nicotiana simulans										18									
N. suaveolens	1																14		16
!*Solanum cleistogamum*																			16
S. esuriale										18									
S. ferocissimum					5					18									16
**S. nigrum*										18				11	12				
Stackhousiaceae																			
Stackhousia monogyna		2	3				7				19								16
Sterculiaceae																			
Brachychiton populneus subsp. *trilobus*								8										15	16
Stylidiaceae																			
!*Levenhookia dubia*						6	7												
Thymeleaceae																			
Pimelea linifolia subsp. *linifolia*											19								
P. trichostachya										18									
Urticaceae																			
Parietaria debilis						6									12				
**Urtica urens*															12				
Violaceae																			
Hybanthus monopetalus	1	2	3	4		6	7	8	17		19								16

	Sandstone											Slate	Granite						Rhyolite
	1	2	3	4	5	6	7	8	17	18	19	9	10	11	12	13	14	15	16
Xanthorrhoeaceae																			
!Xanthorrhoea glauca subsp. *angustifolia*		2																	
Zygophyllaceae																			
Zygophyllum ammophilum										18									
Z. eremaeum										18									
Total number of species	71	68	54	30	44	47	61	64	27	71	45	44	31	37	27	14	40	30	64
Number exotic species	4	12	6	3	7	5	7	8	5	9	7	9	8	11	13	8	14	11	7

Manuscript received 20 March 1991

Manuscript accepted 3 July 1991

The natural vegetation of the Ana Branch – Mildura 1:250 000 map sheet (New South Wales)

Marilyn D. Fox

Abstract

Fox, Marilyn D. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1991. The natural vegetation of the Ana Branch – Mildura 1:250 000 map sheet (New South Wales).* Cunninghamia *2(3): 443–493.* A vegetation map of the Ana Branch and New South Wales portion of the Mildura 1:250 000 topographic maps (SI 54-7 and SI 54-11) is presented. The area is in semi-arid south-eastern Australia (lat. 33°S and south to the Murray River, long. 141°–142°30′E). The vegetation is described and related to soils and geomorphology. A total of 299 species have been recorded from a variety of communities which comprise fifteen map units. Although there are several significant plant communities in the region that are inadequately reserved and seven species are known to be rare or endangered, less than 1% of the area (19,000 km^2) is currently in a formal conservation reserve.

Introduction

Location

The Ana Branch – Mildura map comprises the Australian topographic 1:250 000 Ana Branch sheet (SI 54-7) and the New South Wales portion of the adjacent Mildura sheet (SI 54-11). Figure 1 shows the location of the study area in south-western New South Wales. Although the accepted spelling of the noun anabranch, meaning an alternative or subsidiary course of a river, is as one word, the name of the map sheet is two words. The latter will only be used when referring to the actual map sheet. Figure 2 shows the relevant section of the 1:250 000 map grid, the major rivers and place or homestead/station names. The western boundary of the map is the NSW – South Australian border (141°00′E) while the eastern boundary is 142°30′E which runs just west of Pooncarie to just east of Tarpaulin Bend on the Murray River. The northern boundary is 33°00′S which runs through 'Loch Lilly' near the South Australian border to just north of 'Cuthero' on the Darling River. The southern boundary is the Victorian border along the Murray River, and although politically the border is taken as the southern bank of the river, the vegetation is mapped to the southern extent of the riverine forest. All of the mapped area (with the exception of the Victorian riverine forest) falls within the Western Division of New South Wales. The total area of the map sheet is approximately 19 000 km^2.

The dominant features of the mapped area are the major rivers, the River Murray which flows from the eastern Great Divide to empty into the sea at the Coorong, South Australia and the Darling flowing down from the far north. The divergence of the Darling and its Great Anabranch is only 12 km north of the map. The Darling meets the Murray at Wentworth, the Anabranch follows a more direct southerly bearing and joins the Murray 15 km west of the Darling–Murray confluence.

The many lakes associated with the Anabranch are an important feature of the landscape of this region. Most of the lakes are dry and, after ephemeral flooding,

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some are opportunistically cropped. One of them, Nearie Lake is a Nature Reserve. There is only one lake associated with the Darling River segment covered by this map, it is small Yartla Lake west of Coona Point. The only lakes associated with the River Murray across the Mildura sheet are Lake Victoria in the far west and the Gol Gol swamp and Lake Gol Gol near Mildura.

The principal road north and south is the Silver City Highway which follows the course of the Anabranch and then continues northwards to Broken Hill. The Sturt Highway follows the course of the Murray from the east to the large regional centre of Mildura in Victoria. It then continues due west south of the river. The area is criss-crossed with minor roads and station tracks, most of which are shown on the topographic sheet. A measure of the relative remoteness of this region is that there are no towns on the Ana Branch sheet and only small settlements on the northern bank of the Murray River.

The area is very flat; the average slope is of the order of 1–2 cm /km (Shiel 1980). In general the terrain slopes downwards from north to south and east to west. The regional relief is flat but there are local high and low features. The 250 ft (76 m) contour cuts through the top northwestern corner of the map. Spot elevations printed on the topographic map are Travellers Lake 150 ft (46 m), Nearie Lake 123 ft (38 m) and at the top of Lake Victoria, 102 ft (31 m). The highest point is The Nob 18 km east of Nearie Lake at 176 ft (54 m).

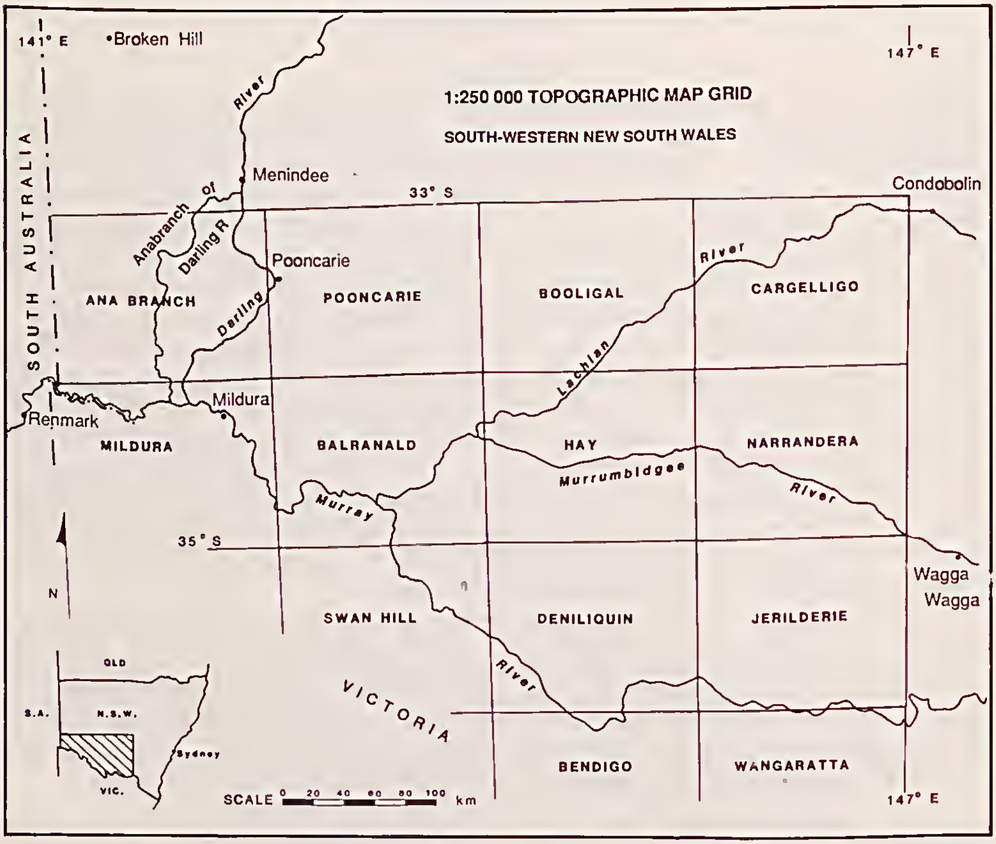

Figure 1. Part of the 1:250 000 map grid showing the mapped sheets and those adjacent to them.

Tectonic history

The entire map area is enclosed within the Murray Basin, a structural basin of 135,000 km^2 evolved from a Tertiary epicontinental basin and Mesozoic and Permian infrabasins (Scheibner 1974). The effective basement of the basin was built in the west by the Adelaide and Kanmantoo Fold Belts and in the east by the Lachlan Fold Belt. There are major faults on the northern and western margins. The study area does not

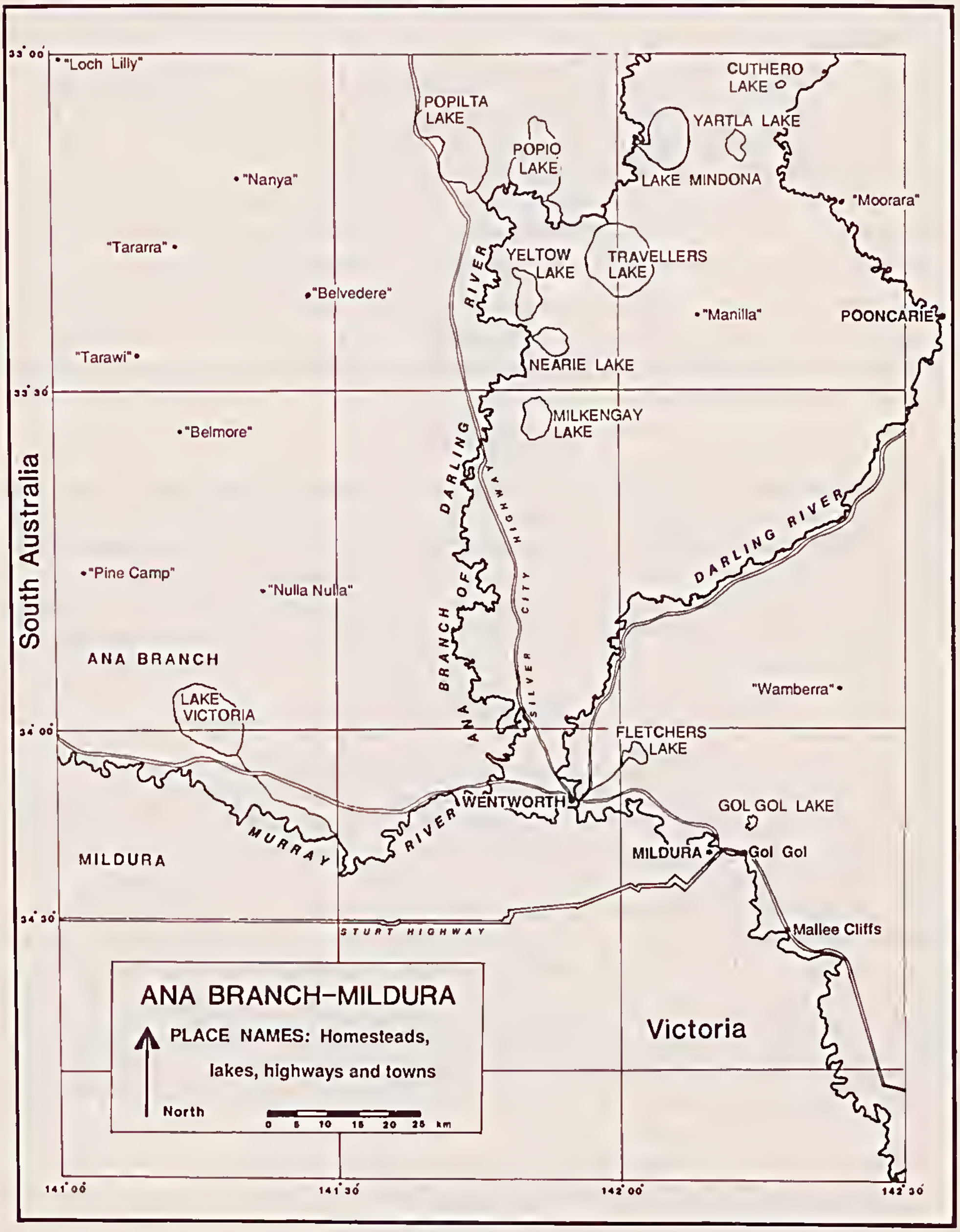

Figure 2. The mapped area comprises two 1:250 000 sheets: Ana Branch and the northern half of Mildura. Major highways, towns and homesteads are shown.

contain any rocky hills or ridges. North of the northern border (south of Broken Hill) there are Cambrian and Precambrian rocks.

The present configuration of the basin has been caused by subsidence and then active sedimentation during the Cainozoic Era. The sediments are extremely thick. A drill-hole near Lake Victoria penetrated bedrock at a depth of 677 m, while nearer Wentworth another went through Permian shale with sand lenses to a conglomerate base at 650 m depth (Pels 1969). On the eastern edge of the Basin are deposits of Tertiary lignites and non-marine, carbonaceous clays up to 360 m thick (Martin 1984). The present landform is a relict Quaternary landform and the contemporary rivers have had little impact (Pels 1969).

The present surface of the mapped area is of entirely Quaternary deposits, principally sands and clays. There are some gypsum deposits near the junction of the Great Anabranch and the Murray. In the far south-west there are some Tertiary outcrops along the Murray River (Pels 1969). A provisional geological map is available (H.N. Ray 1988). The predominant stratigraphy is of Quaternary material comprising fluvial and aeolian deposits. The only other older material are some isolated outcrops of Tertiary sands associated with Murray River and Darling River cliffs.

There are three major aquifers in the sediments of the Murray Basin; these represent glacial peaks and the interbedded clays represent the interglacials (Pels 1969). The hydraulic gradients indicate a general westward and south-westerly direction of groundwater movement.

Palaeohistory

The low-lying area now referred to as the Murray Basin was inundated by shallow marine incursions in the Miocene. These marine transgressions extended as far east as the Willandra lakes (Bowler & Magee 1978). In the Murray Basin the final regression was in the lower Pliocene (Bowler 1982). Following this stage the Murray River was dammed in eastern South Australia producing a large lake, Lake Bungunnia (Firman 1965). The study area falls within the presumed extent of Lake Bungunnia. Palaeomagnetic studies indicate that Lake Bungunnia drained perhaps 700,000 years ago (Bowler 1980a). This would have led to the reworking of the saline basins by both wind and water leading to the present-day aeolian, fluvial and lacustrine landforms.

Over the last major glacial cycle covering the last 120,000 years the south-western region experienced profound changes with the changing precipitation and temperature regimes. From 50,000 to 25,000 years B.P., the increased runoff with reduced evaporation resulted in high groundwater levels and full lakes. About 25,000 years ago the wet phase ended and the lakes shrank and became shallow, saline environments (Bowler 1980a, 1980b). This stage saw the reworking of lake-bed deposits to produce the clay-rich gypseous dunes or lunettes associated with the lakes. At the same time the longitudinal sand dunes were reactivated (Bowler 1976); the last major phase of dune growth was about 15,000 years ago (Bowler 1982). Maximum aeolian activity coincided with the height of glaciation 18,000–16,000 years B.P. (Bowler 1980b, 1982). This extensive aeolian erosion and deposition period, spanning approximately 10,000 years, is the last phase of the shaping of the present-day mallee landforms of the study area.

In the period 15,000 to Present there have been minor oscillations in the hydrologic budget but their effects on landscape development have been subdued. This period saw a general trend to dune stabilisation.

Palaeovegetation

The Miocene-Pliocene interval saw the expansion of the Myrtaceae, Chenopodiaceae and grasslands, together with the contraction of the rainforests (Singh 1982). Myrtaceous fruits occur in Miocene macrofossils, including *Eucalyptus, Leptospermum, Melaleuca, Callistemon* and *Angophora* (Lange 1978). Rainforest with *Nothofagus brassii* persisted in western New South Wales until the end of the Miocene and then was replaced by vegetation rich in Myrtaceae and Casuarinaceae (Martin 1978). The only Pleistocene assemblages found contain much chenopod and composite pollen (Martin 1978), although elsewhere this more open vegetation made its first appearance in the late Pliocene (Truswell & Harris 1982).

Over the past 50,000 years there has been a relationship between high lake levels and high densities of sclerophyll tree vegetation (Dodson 1977). A rise in lake levels 10,000 years ago saw the replacement of eucalypt woodlands by *Allocasuarina verticillata*, and elsewhere *Melaleuca* and *Leptospermum* expanded at the expense of the more open vegetation.

Geomorphology

The present-day landscape is a combination of aeolian, riverine and lacustrine elements. Figure 3 shows the geomorphology of the study area and is based on a map by Bowler and Magee (1978).

The rivers

The major rivers carry water from wetter areas in the north and east, there is no contribution from local surface runoff and hence no eroded channels. Both the Murray and Darling Rivers lose water as they flow westwards. In the past some of the rivers further east, such as the Murrumbidgee, incised prior stream courses and cut over 10 m below the present plain. These incised channels were then filled with Holocene sediments so that now the river beds are only just below the level of the surrounding plain (Pels 1969). Such deposits continue along the Murray River but it is interesting to note that they do not occur along the course of the Darling. The Darling also differs from the Murray and from its own Anabranch by having fewer associated shallow lakes and billabongs. This may reflect a more recent course for the Darling, its previous course being the Great Anabranch.

Linear dunes

These are the stabilised eastern extent of the fossil dunefields of central Australia (Bowler 1980a). The dunes are relatively straight and aligned east-west. They exhibit fairly uniform spacing from 0.2–1.2 km apart and vary in length, but are typically about 3 km long. The linear dunes are quite subdued, commonly with a height differential of only 2–6 m from swale to crest, although in places such as west of the Darling they can be up to 10 m in height. The dunes are composed of reddish-brown sandy clay and sand overlying grey clay. The clay content of the dunes can be as high as 20% in the swales, but is on average half that (Churchward 1963). The carbonate content is on average 5% (Bowler & Magee 1978).

In section the dunes are composed of a series of calcareous palaeosols (Churchward 1961) which represent successive phases of aeolian reactivation. The most recent major phase of dune growth was about 15,000 years ago (Bowler 1982). The long period of stability was maintained by thick vegetation cover. When that was removed by fire and clearing with settlement of the region some of the dunes were reactivated.

Irregular sub-parabolic dunes

These are steep, irregular siliceous dunes, sometimes called jumbled dunes. These are still influenced by prevailing westerly winds so that the apex of the parabola points east. Irregular dunes crests are commonly more than 10 m above the swales and their flanks are steep. Although their spacing is irregular these dunes are closer than the linear dunes. There are some irregular sub-parabolic dunes south of Pooncarie, east of the Darling River.

Sand plains

On the Ana Branch – Mildura map sheet there is a discontinuous belt of sand plain following the Darling and Anabranch and this is typical of the Interactive Zone of Mabbut (1980). This represents the zone of overlap and interaction between the aeo-

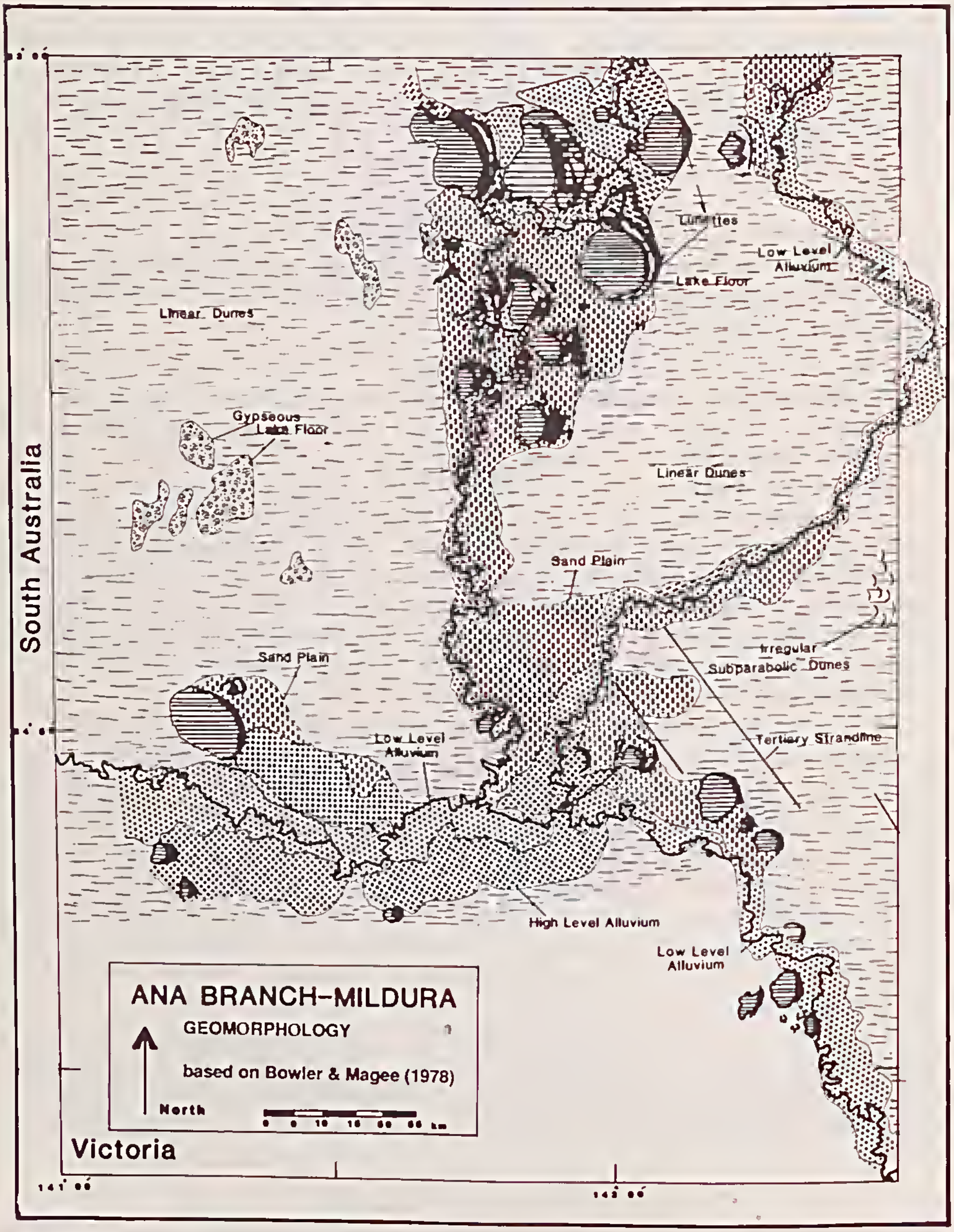

Figure 3. The geomorphology of the mapped area based on a map by Bowler & Magee (1978). The most extensive unit is the linear dunefield. A series of alluvial units is associated with the rivers and lakes.

lian and fluvial systems. It comprises irregular sand accumulations which are roughly circular mounds from less than 100 m to over 3 km in diameter. The larger mounds can be over 30 m in elevation. These are more similar to the linear dunes in composition, comprising sands and sandy clays with layered palaeosols and catenary profile differentiation (Rowan & Downes 1963).

Lunettes

These distinctive structures are smooth crescentic transverse dunes on the eastern and south-eastern sides of lake basins. Lunettes commonly have a 'core' of clean quartz sand which was deposited when the lake was full (e.g. Bowler 1980). Then saline gypseous clay mantled the sand core when the lake dried out. The last episode of lunette building was 19,000–15,000 BP (Bowler & Magee 1978). The lunette height and size is proportional to the size of the lake. On the Ana Branch – Mildura sheet there are well-developed lunettes on Popiltah, Popio and Mindona Lakes, but all the smaller lakes associated with the Anabranch also have defined lunettes. The lunette on Travellers Lake is composed entirely of quartz sand. It never experienced the suitable dry saline conditions necessary to deposit the gypseous clay layer over the sand.

Lake floors

The lakes of the south-west are well defined by the sharp break in slope on their western margin and a lunette on the eastern side. The lakes are typically smoothly elliptical or often kidney-shaped with the long axis aligned roughly north-south.

On the Murray river the principal lake is Lake Victoria near the South Australian border. This is now used as water storage as part of the water conservation-irrigation system of the lower Murray. The Anabranch has an important chain of lakes associated with it which are subject to occasional flooding. However, most of the time the lakes are dry and the lake floors comprise fine-grained clays with silts and sands more prominent in the deposits of the eastern down-wind margins. The dry lake floors are commonly criss-crossed by large dessication cracks. The salt content of the floor is high, supporting a salt-tolerant vegetation.

Gypseous lake floor

West of the Anabranch there are some large, irregular, low-lying areas that have been sites of groundwater evaporation. A preliminary shallow groundwater and salinity map of the Murray Basin (Evans 1988) shows these. For example, the Huntingfield groundwater discharge basins north of Lake Victoria total 443 km^2 and comprise highly saline, gypseous and calcareous clays, with lunettes of cemented siliceous sands (Eldridge 1985). However, not all gypseous lake floor areas have well-defined lunettes and they are usually in regions remote from drainage lines. Large areas of active groundwater discharge are termed boinkas (Macumber 1980).

Alluvium

Near the junction of the Darling and Murray Rivers there are high level alluvial terraces that post-date the linear dunefields. The laminated deposits are dominantly fluviatile and are of mixed ages. Lower level alluvium comprises the modern floodplain and follows the major drainage channels throughout the region. West (downstream) of Wentworth the Lower Alluvium forms a flat alluvial plain below the level of the older Upper Alluvium (Figure 2).

Clay plain and clay plain with sand cover

These features occur east of the dunefields in the large areas between major drainage lines such as between the Darling and the Great Anabranch.

Soils

The Ana Branch – Mildura region is part of the Murray–Darling Plains (Vll) of Butler, Blackburn & Hubble (1983). More specifically it is part of their Soil Landscape Province 3, the Murravian Gulfland. Butler (1980) presents a detailed account of the soils of the Mildura region. The aeolian soils of south-western New South Wales has been described by the Soil Conservation Service of NSW (Eldridge 1985). A series of 1:250 000 soils maps is incorporated with detailed notes on the 32 soil-landform associations identified. Figure 4 is based on the Ana Branch and Mildura maps from Eldridge (1985). The figure is considerably simplified but shows the distribution of the eight main soil groups.

The **calcareous sands** (Unit 1, Figure 4), on longitudinal dunefield are restricted to the north-western corner of the linear dunes unit of Figure 3, and to an area west of Lake Victoria. The other soil units associated with the linear dunes are Unit 6 (brown calcareous earths), Unit 7 (grey-brown calcareous earths) and Unit 8 (brown sands/calcareous earths). Units 6 and 7 are found mainly west and east of the Anabranch of the Darling, but not east of the Darling. Unit 8 is found principally east of the Darling and not west of the Anabranch. The siliceous sands (Unit 2) on sub-parabolic dunes correspond to the irregular sub-parabolic dunes in the far east of the map.

The **saline and gypseous clays** (Unit 4) are found on the gypseous lake floor areas principally west of the Anabranch.

The **red duplex soil** (Unit 5) partly corresponds to the sand plain of Bowler & Magee (1978, Figure 3), and is associated with the Anabranch lakes and with the confluence of the rivers. The river course itself, principally the low level alluvium of Figure 3, is shown here as Unit 3, the grey cracking clays. This unit follows the rivers and includes the lake beds.

All the soils are coarse-textured and prone to wind erosion when the vegetative cover is removed. Where the soils are irrigated there is a problem with salinization as deeper saline waters are drawn to the surface. There are associated changes in floristic composition with the spread of weeds, the loss of useful native perennial species and the increase in some unproductive native shrubs. With cropping there are changes in soil structure and loss of soil nutrients. All of these changes associated with cultivation are addressed in Lievers & Luke 1980, Eldridge & Semple 1982, Stanley 1982, and Walker 1982.

Land systems

The land systems of western New South Wales have been mapped by the Soil Conservation Service of New South Wales. Descriptions of land systems typically comprise combinations of landform, soil and vegetation. Lawrie & Stanley (1980) present an overview of the land system mapping program and describe the eight land systems representative of the mallee lands. The Ana Branch land system map (Eldridge 1985) shows four geomorphological classes: sandplains, dunefields, alluvial plains and playas or basins with respectively 10, 7, 5 and 7 units.

Climate

The climate of the Murray Darling Region has been summarised in the Bureau of Meteorology's Climatological Survey: Region 19 (1955). This summarises information on temperature, evaporation, rainfall and sunshine for the mapped area and to east of the Lachlan River. The region is also covered in a publication on rainfall with special reference to soil conservation (Edwards 1979).

The mapped area falls within the semi-arid region of south-eastern Australia. Rainfall is highest in the south-east (long-term average rainfall Mildura 295 mm, Wentworth

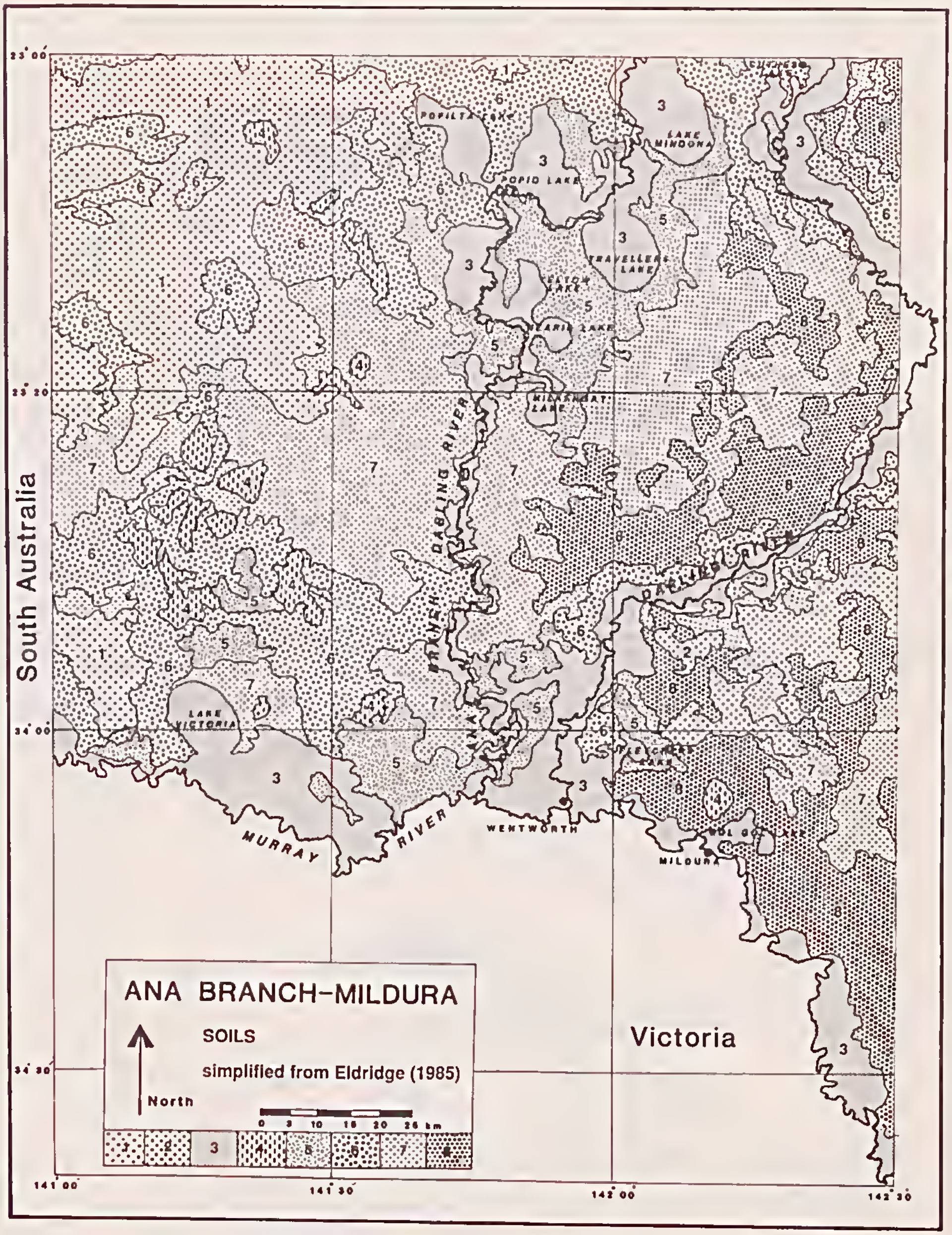

Figure 4. The soils of the mapped area based on maps in Eldridge (1985). **1.** Calcareous sand, dunefield. **2.** Siliceous sand, sub-parabolic dunes. **3.** Grey cracking clays. **4.** Saline and gypseous clays. **5.** Red duplex soil. **6.** Brown calcareous earths. **7.** Grey-brown calcareous earths. **8.** Brown sand/calcareous earths on aligned dunes.

289 mm) and diminishes gradually to the north (Cuthero 247 mm, Broken Hill 249 mm and Menindee 237 mm). Figure 5 shows the long-term (all available records) pattern of rainfall distribution for seven stations on or close to the mapped area. Whereas they all have long-term averages of 200–300 mm, they have received a variable annual amount of rain from less than 100 mm to more than 450 mm, in exceptional years with over 700 mm. This variability in annual rainfall is illustrated in Figure 6 for two of these stations. The long-term average is shown as a dashed line

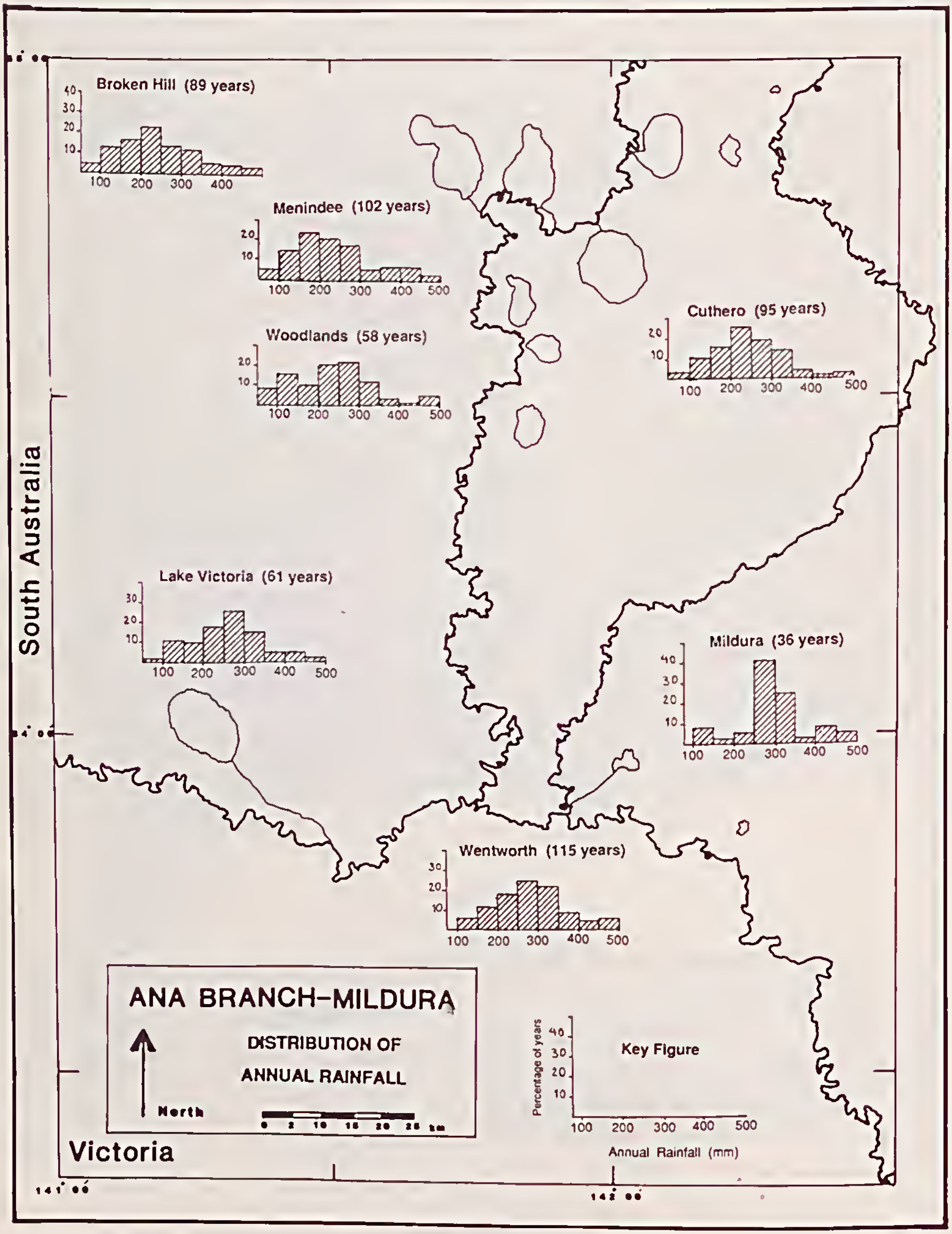

Figure 5. The long-term distribution of rainfall for seven stations on or close to the mapped area (all available data from Bureau of Meterology).

and the yearly values are illustrated. Years of high rainfall such as 1974 are exceptional and may be twice or three times the average annual value.

Figure 7 illustrates the climatograms for five stations on or near the map sheet. Climatograms are designed to show the seasonal fluctuation in water availability (e.g. Walter & Lieth 1967). The average temperature is plotted on the left hand axis and the monthly rainfall on the right hand axis. The stippled portions of the figure

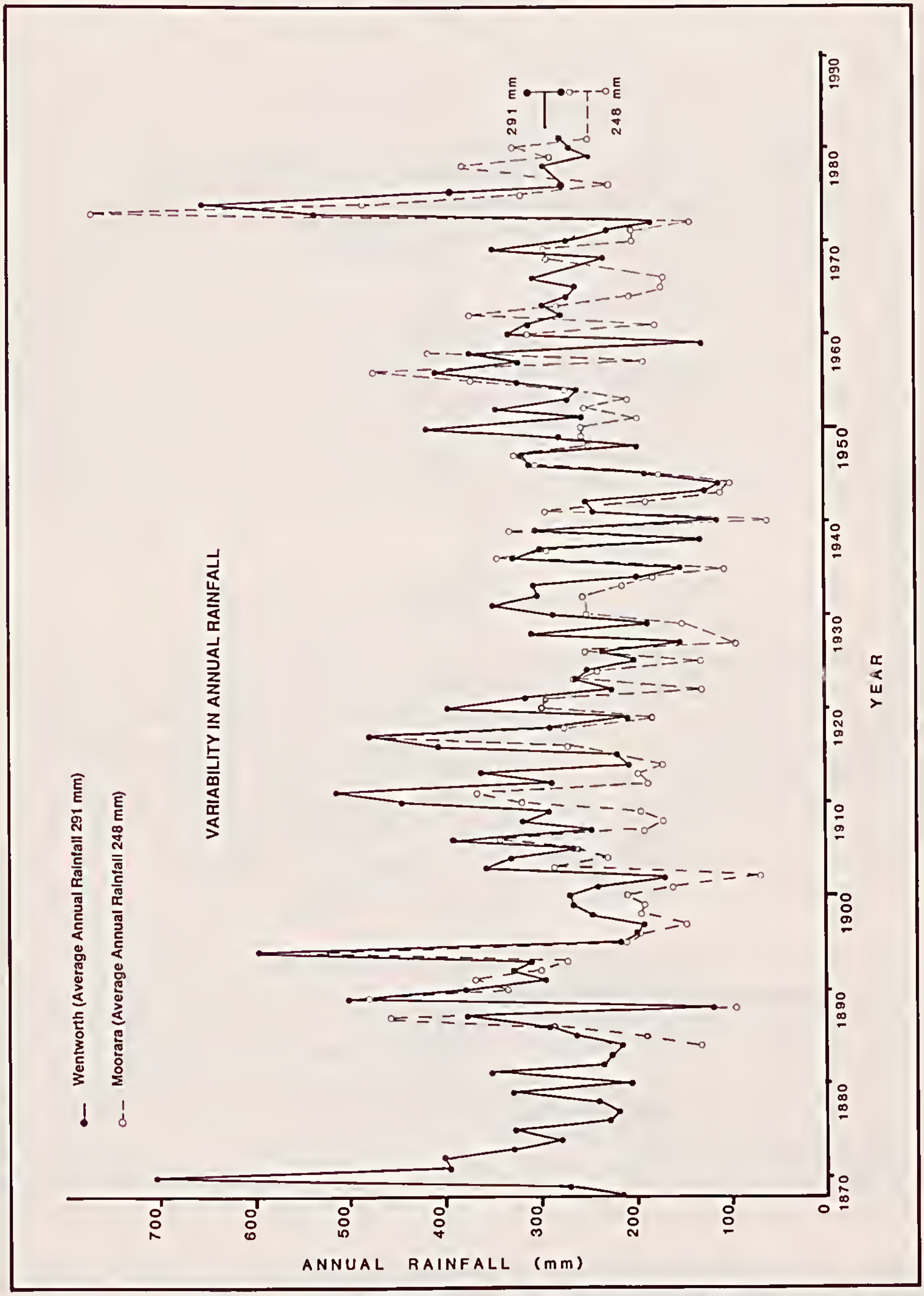

Figure 6. Long-term rainfall record for two stations on the mapped area illustrate the high year-to-year variability.

represent the time of high temperature (and therefore high evaporation) and low rainfall when vegetation would experience moisture deficits. The vertical hatched portion is the winter period when rainfall (especially in the south) is adequate and temperatures are low. All stations may receive rainfall in any month but there is a winter influence in the south which becomes stronger towards Adelaide in the true 'Mediterranean' climatic regions of southern Australia.

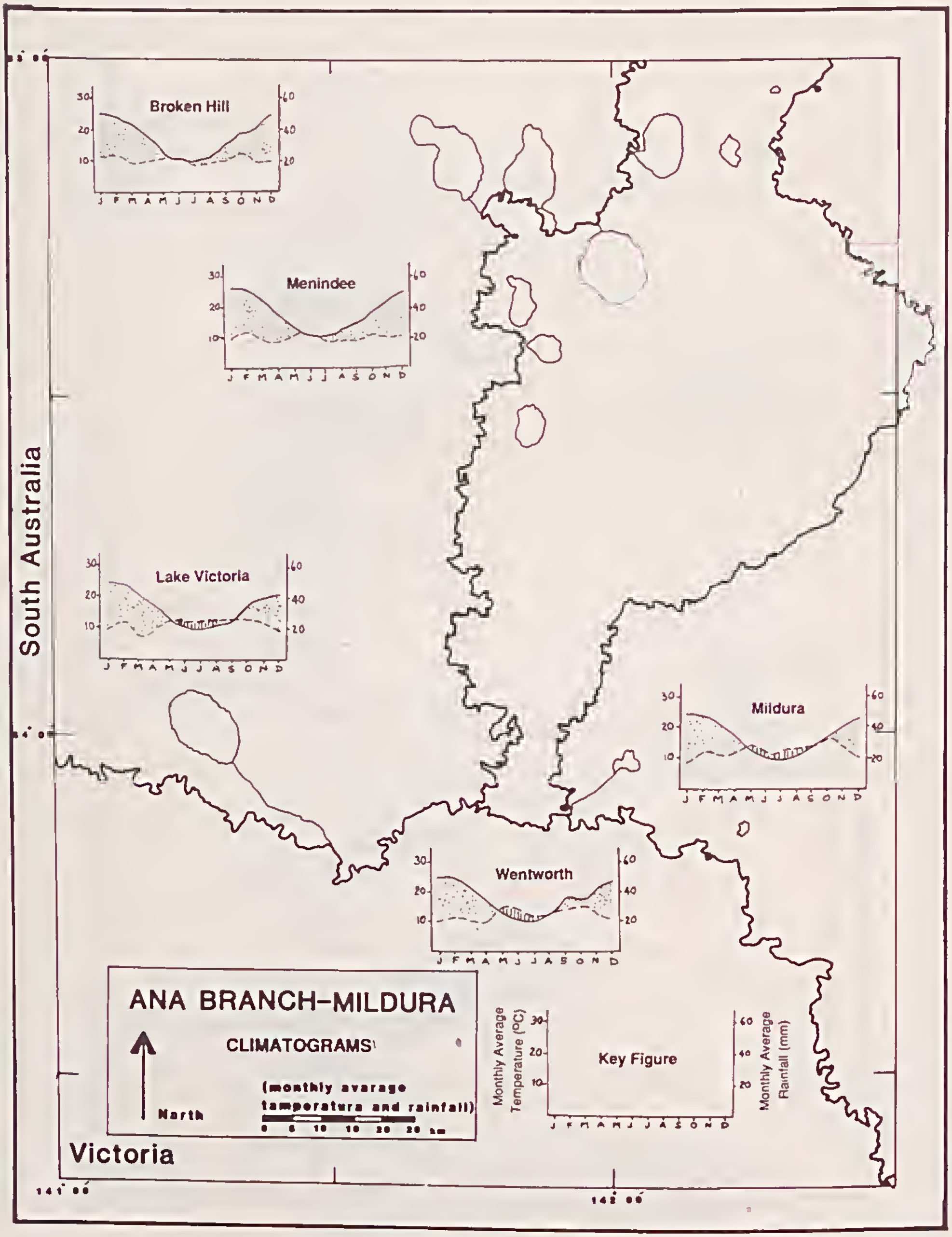

Figure 7. Climatograms for five of the weather stations on or near the mapped area. The figures plot monthly average temperature and rainfall and demonstrate the relatively wet winters in the south of the mapped area.

The region experiences high summer temperatures and high incident radiation, resulting in high evaporation. Winter temperatures do go below freezing point at night and frosts may occur on 10% of winter nights. Effective rainfall occurs in the winter months but absolute amount and distribution varies from year to year.

Vegetation

The natural vegetation of the mapped area has received some treatment in the scientific literature. Cambage (1914) presented an early treatment of the flora of the west Darling country. Beadle (1948) prepared a comprehensive account of the whole of the Western Division which includes this mapped area. He also produced the only published vegetation map of the Western Division (Beadle 1945). A section of his map is reproduced in Figure 8. Two principal vegetation types predominate, and both are associated with the linear dunefield and sub-parabolic dunes. These are mallee (Unit 1, Figure 8) and *Casuarina* woodland (Unit 2). Along the river alluvium is the third unit, a *Eucalyptus* woodland. Shrublands dominated by members of the Chenopodiaceae occur on the sandplain and high level alluvium (Figure 3). These comprise one association of species of *Maireana* (Unit 4) and one of *Atriplex vesicaria* (Unit 5). This is an over-simplification of the range of vegetation types present but serves to illustrate the basic simplicity of the system. Just as there are relatively few geomorphological units, there are relatively few vegetation types. The vegetation comprises structurally simple, low woodlands or shrublands; the only tall forest vegetation is a narrow band of riverine *Eucalyptus* forest along the rivers and associated channels.

Aboriginal history

Four tribal groups occupied country covered by the Ana Branch – Mildura map. These were the Wilyali from the far northwest of the area, the Bolali from west of the Anabranch, and further south, the Yu-Yu from near Lake Victoria. To the north of Pooncarie were the Bagundji (Moore 1979). The Bagundji's territory extended along much of the course of the Darling river and to the west of it (Allen 1979). Allen lists the following tribes as belonging to this tribal group: Bagundji, Barindji, Danggali, Bolali, Wilyagali, Bandjigali, Wanywalgu and Baruńdji. (Some of these are alternative spellings for the tribes listed by Moore 1979.) These all belonged to the Wiradhuri nation (Moore 1979). This group of tribes occupied the basins of the Murray, Murrumbidgee and Lachlan rivers.

The Darling River region supported a large Aboriginal population. The river and plains offered abundant resources and Aboriginal groups were larger and less nomadic than those in higher rainfall areas further east (Allen 1979). Aboriginal use of native plants is only partially known, but the use of the rhizomes of *Typha* spp. is well documented, as is the harvesting and preparation of seed from Native Millet, *Panicum decompositum* (Allen 1979). Seeds of Pigweed, *Portulaca* sp., and the sporocarps of Nardoo, *Marsilea drummondii*, were also used. During winter the seeds of Saltbush (*Atriplex* spp.), Wattles (*Acacia* spp.) and Flax plants (*Linum marginale*) were eaten (Cribb & Cribb 1974). Allen (1979) lists 24 plants eaten by the Aborigines of the Darling Basin.

The main evidence of pre-European Aboriginal activities are the 'canoe' trees, usually River Red Gum, *Eucalyptus camaldulensis*, but also Black Box, *E. largiflorens*. These trees are scarred by the removal of large ovals of bark and sapwood for the manufacture of small canoes and coolamons for carrying babies or food. Since there are no rock outcrops in the mapped area there are few rock-associated artefacts, although imported stone tools have been found.

Creamer (1979) maps two massacre sites close to and just east of Lake Victoria. Burial mounds may have occurred but have been obliterated over time. Oxley excavated several mounds near the Lachlan River in 1820. These were sometimes surrounded by decorated trees.

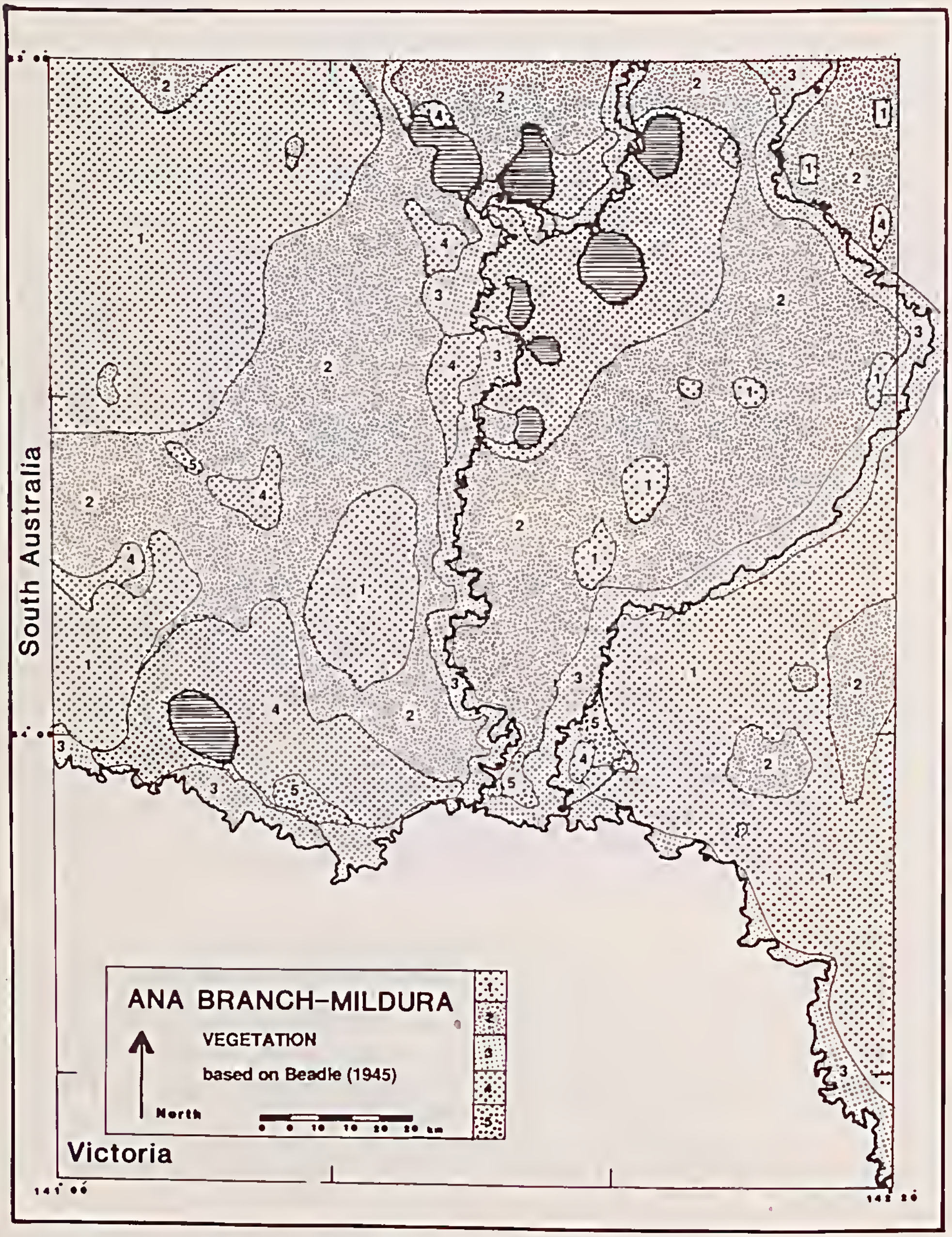

Figure 8. The vegetation of the mapped area based on a map by Beadle (1945). 1. *Eucalyptus socialis – E. dumosa* association. 2. *Casuarina–Alectryon* association. 3. *E. largiflorens* association. 4. *Maireana pyramidata – M. sedifolia* association. 5. *Atriplex vesicaria* association.

Within the mapped area there is a very significant archaeological site in the lunette of Lake Victoria (Marshall 1973). Two other sites are located just north of the mapped area in the lunette of Lake Tandou and Lake Menindee. Here fossils of extinct Pleistocene animals such as *Diprotodon, Protemnodon, Sthenurus* and *Procoptodon* have been found (Merrilees 1973). To the east are the famous sites associated with the Willandra lakes. The best-dated faunal material from the late Pleistocene of semi-arid Australia has been derived from lunettes in western New South Wales (Hope 1982).

European settlement

The history of European occupation of the Far Western Plains of New South Wales began with the exploration along the river courses by British explorers. Captain Charles Sturt explored along the length of the Murray River in 1828 and 1830. Sturt reached the Darling in 1829 and named it in honour of Governor Ralph Darling, although the river had been crossed in its upper reaches by Allan Cunningham in 1827. Major Thomas Mitchell explored the northern half of the Darling in 1835 and later confirmed Sturt's assertion that it joined the Murray.

Pastoral settlement spread slowly west from Sydney and northwards from the more fertile areas of Victoria. The whole of the mapped area falls within the 1858 Police District of Balranald (Robinson 1976) which was subdivided by 1865 to a number of smaller districts of which Wentworth covers most of the mapped area. An indication of the rate of settlement comes from the wheat harvests for each Police District. The figures for Balranald are nil (1861), 7 acres (1866), 14 acres (1871), nil (1876) and 385 acres (1879). No acreage is given for Wentworth during this period. The land had largely been settled by 1860 and the principal pursuit was, and still is, running sheep. In the 1870s seasonal conditions were good and there was a rapid increase in sheep numbers. By 1877–1891 stock numbers had increased to two to three times those of today. A prolonged drought that ended in 1902 saw numbers crash to half of present levels. A Royal Commission was held into the western leasehold pastoral lands in 1901. It found that the low rainfall, extensive rabbit infestation, overstocking and subsequent erosion combined with high rentals, low wool prices, property depreciation and financing difficulties were all factors contributing to the plight of Crown Tenants in the Western Division. The Western Lands Act of 1901 arose from the recommendations of the Commission. An overview of the history of pastoralism is given in Condon (1983).

In an area with low and unpredictable rainfall the land away from the rivers could only be used in periods of good rain until the introduction of well sinking and tank formation in the late 1860s. Until the introduction of windmills, water was pumped by people or horsepower (Condon 1976). Quite early in the history of settlement there were ambitious schemes to irrigate the land away from the rivers and the Chaffey brothers introduced irrigation schemes at Mildura and Renmark in the 1880s.

Previous vegetation surveys

There have been a number of previous vegetation surveys covering part or whole of the mapped area beginning with Cambage (1914). In 1923 Albert Morris, famed for his revegetation of the environs of Broken Hill, published an account of the flora between the Darling River and Broken Hill (Morris 1923); this relates mainly to the vegetation to the north of the map sheet but is relevant to the region. Also in 1923, Marjorie Collins published the first of a series of papers on the vegetation of arid and semi-arid New South Wales (Collins 1923). Again this paper, on the vegetation of the Barrier District, deals with a region largely north of that treated here.

The most comprehensive treatise on the vegetation of western New South Wales is 'The Vegetation and Pastures of Western New South Wales' (Beadle 1948) with an accompanying coloured vegetation map at a scale of 1" = 16 miles (c. 1:1 000 000)(Beadle 1945). More recently, Beadle (1981) includes chapters that describe the vegetation communities of the west in his book on the vegetation of Australia. Other general accounts of major vegetation types are chapters by Johnson & Burrows (Acacia communities), Parsons (mallee) and Leigh (chenopod shrublands), in Groves (1981). Noble & Mulham (1980) summarise the features of the mallee communities. A more quantitative account of the vegetation of the semi-arid region of south-eastern Australia was published by Noy-Meir (1971) and an unpublished vegetation map (1:1 000 000) was produced by the same author in the course of his work (Noy-Meir 1981).

To the east of the map sheet lies Mallee Cliffs National Park and a recent publication has mapped its vegetation and described the communities (Morcom & Westbrook 1990). Further south of the mapped area, in north-western Victoria, Connor (1966) reported on the vegetation of the Beulah–Hopetoun area in a series on the vegetation of the north-west of Victoria. Also in northwestern Victoria, Gullan (1991) describes the practicalities of floristic mapping in the Victorian mallee, the region due south of the Ana Branch – Mildura map.

The flora of the region

Several published species lists cover the map area. Semple (1985) lists the vascular plants of the mallee communities of south-western New South Wales. Semple (1986) lists the vascular plant species for the riverine plain, many of which occur on the alluvial landforms of the mapped area.

The book 'Plants of Western New South Wales' (Cunningham, Mulham, Milthorpe & Leigh 1981) includes an account of the vegetation of the region as well as photographs and notes on the flora of the area. The book describes 2027 species of vascular plants, including 19 species of ferns. These species represent 635 genera from 129 families. The most abundant families are the Poaceae (297 species), Asteraceae (265 species), Chenopodiaceae (146 species), Faboideae (137 species) and Mimosoideae (80 species). The authors also describe 407 species which are established in natural communities but are not native to Australia. This compilation is for the whole of the Western Division which cover four botanical subdivisions (see map at back of issue), viz the North Western Plains (NWP), South Western Plains (SWP), North Far Western Plains (NFWP) and South Far Western Plains (SFWP). The Ana Branch – Mildura map sheet falls within the last of these. Table 1 lists the total number of species in six broad categories for the four botanical subdivisions.

There are a number of interesting features in the tallies shown in Table 1. In each division the northern subdivision is richer in all groups than is its southern counterpart, except for conifers, which are richer in the south. The other gross pattern is the greater richness of the Western Plains compared with the more arid Far Western Plains. There are also proportionally more monocotyledons to dicotyledons in the Western Plains subdivisions (0.33 N and 0.30 S) than in the Far Western Plains (0.22 N and 0.16 S). This is largely influenced by the grasses of which there are 215 species in the Western Plains and only 121 in the Far Western Plains.

Some families are better represented in the Far Western Plains. For instance the chenopods (Chenopodiaceae) number 104 species in the Western Plains and 134 species in the Far Western Plains. Other families such as the Fabaceae or other groups such as Mimosoideae (Fabaceae) have over twice as many species on the Western Plains (84 species) as on the Far Western Plains (37 species). Some families are almost

Table 1. The number of plant species in broad taxonomic categories for the four Botanical Subdivisions in western New South Wales (numbers based on Jacobs & Pickard 1981, ferns from Cunningham et al. 1981).

Plant group	**Botanical sub-division**				**Total all Western Plains**
	NFWP	**SFWP**	**NWP**	**SWP**	
Cycads	0	0	1	0	1
Conifers	2	3	3	4	4
Monocotyledons	154	80	306	217	405
Dicotyledons	710	512	936	727	1370
Exotic monocots	37	(37)	108	(108)	117
Exotic dicots	134	(134)	284	(284)	310
Total native species (excluding ferns)	866	595	1246	948	1775
Total exotic spp.					427
Total ferns (Cunningham et al. 1981)					19
Total vascular plant species					**2226**

equally abundant in the two divisions, especially when the larger area of the Western Plains is taken into account. The Asteraceae are represented by 182 species in the Western Plains and 150 species in the Far Western Plains. The subdivision in which the map sheet falls has a total of 595 species recorded in Jacobs & Pickard (1981).

Structural vegetation types

Vegetation types are described by structural attributes, principally height of the tallest stratum and percent foliage cover (Specht 1981). The floristic associations are then used to further distinguish the vegetation unit. Table 2 lists the structural formations and floristic alliances represented in south-western New South Wales (from Specht et al. 1974). The height range and foliage cover range for each alliance are given.

Methods

Vegetation mapping

Initial air photo interpretation employed composite photomosaics (1:50 000) based on 1964–65 aerial photos (NSW Department of Lands). Different photopatterns were recognised and marked directly on the mosaics. These were then traced onto film and reduced to the provisional mapping scale of 1:100 000. These boundaries were transferred to topographic maps at the same scale. These topographic maps are particularly useful, showing most station tracks and locations of dams and bores accurately. By comparison with the only published vegetation map of the region (Beadle 1945) tentative names were assigned to the photopatterns and then confirmed or reassigned after field inspection. Because of the scale of vegetation patterns in the mapped region and the flatness of the terrain, it was considered inappropriate to use stereoscopic pairs of air photographs.

Table 2. Structural formations and floristic alliances represented in south-western New South Wales (from Specht et al. 1974). The height range (m) and foliage cover range (%) for each alliance are given.

Structural formation	Floristic alliance	Height. (m)	Cover (%)
Open-forest			
Swamp sclerophyll forest	*Eucalyptus camaldulensis*	10–30	30–70
Woodland			
Savannah woodland	*Eucalyptus largiflorens*	10–30	10–30
Low open-forest			
Mallee	*Eucalyptus socialis – E. dumosa*	5–10	30–70
Low woodland			
Fringing woodland	*Eucalyptus camaldulensis*	5–10	10–30
Fringing woodland	*E. largiflorens*	5–10	10–30
Low open woodland			
Fringing woodland	*Eucalyptus largiflorens*	5–10	<10
Closed shrub			
Lignum swamp	*Muehlenbeckia cunninghamii*	2–8	70–100
Open shrub			
Mallee	*Eucalyptus socialis – E. dumosa*	2–8	30–70
Arid shrubland	*Casuarina pauper – Alectryon oleifolius*	2–8	30–70
Tall shrubland			
Mallee	*Eucalyptus socialis – E. dumosa*	2–8	10–30
Arid shrubland	*Casuarina pauper – Alectryon oleifolius*	2–8	10–30
Open heath			
Saltbush	*Atriplex vesicaria*	0–2	30–70
	Maireana spp.	0–2	30–70
	Chenopodium nitrariaceum – Eremophila maculata	0–2	30–70
	Atriplex inflata	0–2	30–70
Low shrubland			
Saltbush	*Atriplex vesicaria*	0–2	10–30
	Maireana spp	0–2	10–30
	Chenopodium nitrariaceum – Eremophila maculata	0–2	10–30
	Atriplex inflata	0–2	10–30
Saltpan	*Sclerostegia tenuis – Minuria cunninghamia*	0–2	10–30
Low open-shrubland			
Saltbush	*Atriplex vesicaria*	0–2	<10
	Maireana spp.	0–2	<10
Herbfield/grassland			
Canegrass swamp	*Eragrostis australasica*	0–2	30–70
Sedgeland			
Swamp	*Azolla* sp.	0–2	30–70
Saltpan	*Sclerostegia tenuis*	0–2	30–70
Arid herbfield	Ephemerals	0–2	30–70
Open sedgeland			
Saltpan	*Sclerostegia tenuis*	0–2	10–30

Survey techniques

Field surveys were conducted over a period from late 1979 to 1989 in a variety of seasons. Figure 9 shows the principal field traverses along roads and station tracks. As well as these, excursions were made on foot to areas that were difficult to reach by vehicle.

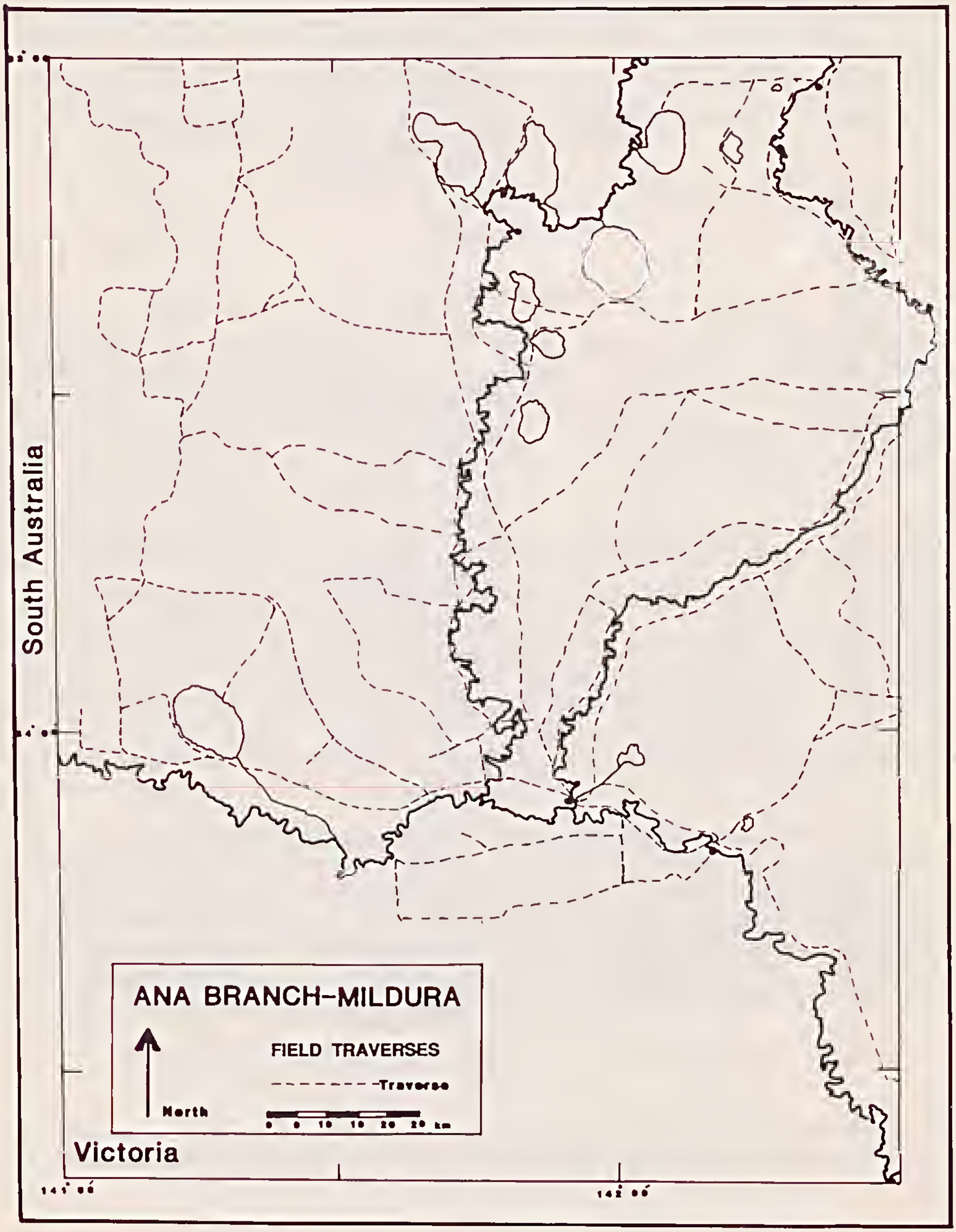

Figure 9. Location of major field traverses completed in the vegetation survey of the mapped area.

Table 3. Map unit descriptions

No.	Code	Structure	Main species	Dominant plant community
1	eM3F	Open-forest	*Eucalyptus camaldulensis*	Riverine Forest
2	eM2S	Low open woodland	*Eucalyptus largiflorens* *Atriplex nummularia*	Black Box Woodland
3	eS2H	Tall shrubland	*Eucalyptus socialis* *E. dumosa*	Dune Mallee
4	cS2Z	Tall shrubland	*Casuarina pauper* *Alectryon oleifolius* subsp. *canescens*	Arid Shrubland
5	eS2H/ cS2Z	Tall shrubland	Mosaic of 3 with 4	Arid Shrubland
6	cS2Z/ eS2H	Tall shrubland	Mosaic of 4 with 3	Arid Shrubland
7	cS2Z/ eS2H/ kZ2F	Tall shrubland	Mosaic of 4, 3 & 8	Arid Shrubland
8	kZ2F	Low shrubland	*Maireana pyramidata* *Rhagodia spinescens*	Black Bluebush
9	kZ2F	Low shrubland	*Maireana sedifolia* *Erodium* spp.	Bluebush
10	kZ2F	Low shrubland	*Maireana pyramidata* *Atriplex* spp.	Lunette Shrubland
11	kZ1F	Low open-shrubland	*Atriplex vesicaria* *Sclerostegia tenuis*	Bladder Saltbush
12	kZ1F	Low open-shrubland	*Sclerostegia tenuis* *Atriplex* spp.	Pigface-Samphire
13	yG3F	Grassland	*Eragrostis australasica*	Canegrass Swamp
14	gG3F	Sedgeland	*Eleocharis pallens*	Sedge Swamp
15	kF2F	Open herbland	*Disphyma clavellatum* *Sclerostegia tenuis*	Saltpan, Lakebed

Plant communities too small to be shown as separate map units

Code	Structure	Main species	Dominant plant community
eS2H	Tall shrubland	*Eucalyptus oleosa*	Sand Plain Mallee
eS2H	Tall shrubland	*Eucalyptus gracilis*	Swale Mallee
pM2S	Open woodland	*Callitris glaucophylla*	Mixed Woodland
wS3F	Tall shrubland	*Acacia victoriae*	Acacia Shrubland
xS4F	Closed shrubland	*Muehlenbeckia cunninghamii*	Lignum Swamp
kS3F	Tall shrubland	*Atriplex nummularia*	Old Man Saltbush

Map units show original vegetation cover before European settlement, as interpreted from aerial photography and field survey. Present vegetation has been affected by widespread grazing and localised clearing.

After the initial mapping stages, provisional maps (at 1:100 000) were taken into the field and checked. Sites were established in all the map units so as to characterise the vegetation. A set of permanent sites was established in the drought year of 1982 across south-western NSW, some of these were in Kinchega National Park just north of the mapped area. Sites usually comprised a rectangular quadrat 100 m long by 40 m (0.4 ha). This was searched methodically and all identifiable vascular plant species recorded. Specimens were taken for verification and these are lodged in the National Herbarium of NSW. The structure of the vegetation was recorded as the height of the different strata and their respective projected foliage cover. Notes were made on the condition of the vegetation, the soil type, any evidence of fire, grazing, weed infestations, erosion. At a subset of sample points, soil samples were collected from the top 40 cm and analysed by the NSW Department of Agriculture's chemistry laboratory for exchangeable cations, pH and electrical conductivity.

Results

The vegetation types

The principal structural formation is the shrubland, either low open-shrublands dominated by members of the Chenopodiaceae, or tall shrublands dominated by mallee eucalypts and *Casuarina pauper*. The only tall forests are the River Red Gum forests fringing the rivers. Elsewhere on the periodically flooded flats are extensive woodlands of *Eucalyptus largiflorens*. Table 3 provides a concise description of the fifteen units mapped.

The distribution of these map units is shown on the vegetation map (back pocket). The map shows vegetation as it is assumed to have been before European setlement. Map units do not always correspond with single communities. There are vast areas with mixtures of two or more communities which cannot be separated at this mapping scale. The reason for the amount of intermingling is the nature of the landscape with, for example, shallow sand mantling heavier clay alluvium. In such a case there may be linear patches of mallee on the sand and *Casuarina* woodland in deflated areas where the heavier soil is exposed. There are other plant communities whose occurrences are always too small to map at this scale. They are described in the section on Plant Communities.

Map units are coded by the alphanumeric code used by Carnahan (1989). This is a four-character code, with the first three characters for the tallest stratum and the last one for the lower stratum. For example eS2H signifies that the predominant genus in the tallest stratum is *Eucalyptus* (e), the growth form is tall shrub (S) with 10–30% foliage projective cover (2), and the lower stratum is dominated by hummock grasses (H). In other words, this unit is mallee with *Triodia* understorey. The full key and explanation are given on Carnahan (1989).

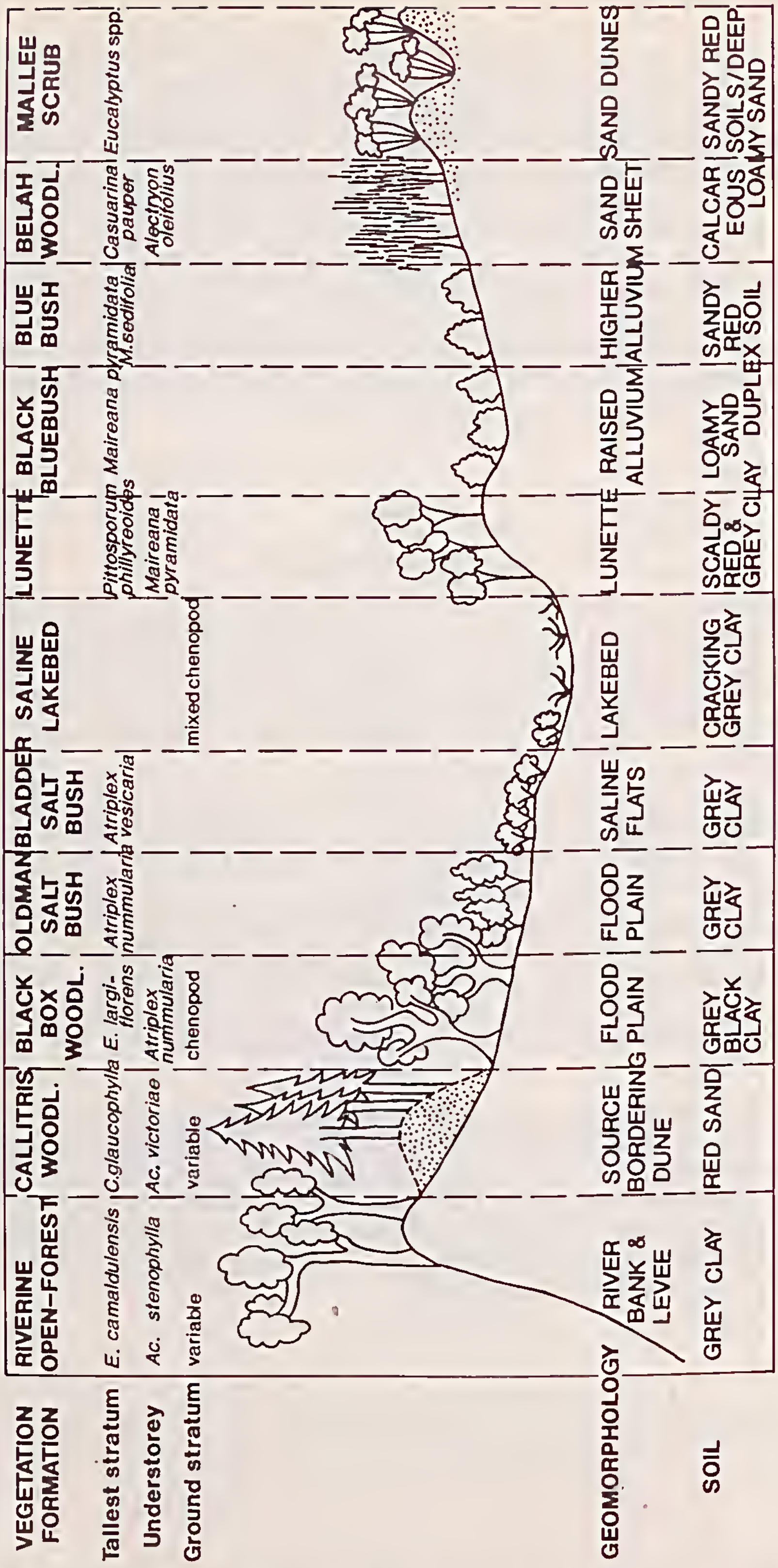

Figure 10. Idealised vegetation continuum from river to sand dunes showing relative topographic arrangement of major vegetation types.

The plant communities

Figure 10 is a highly simplified and stylized profile of the landscape to show the relative occurrences of the plant communities.

1. Riverine Forest, River Red Gum Forest

Map units: 1 (2)
Code: eM3F
Structural formation: Open-forest
Height: 25–40 m
Cover: 30–70%
Dominant species: *Eucalyptus camaldulensis* on levees: *E. largiflorens* on flats and along smaller streams.
Understorey species: *Acacia stenophylla, Chenopodium nitrariaceum, Melaleuca lanceolata.*
Ground layer: Mix of herbaceous species, many exotics
Species richness: (0.1 ha) 23.4 ± 4.1 (n=5)
Landform: River levees and flats between braided streams.
Habitat (photopattern): Often concentric linear photopatterns with oxbows
Soil: Heavy grey alluvium
Degradation/regeneration: Subject to frequent and prolonged flooding, major regeneration occurs as floods subside leading to 'wheatfield' regeneration of extremely dense seedling growth which gradually thin out as plants grow. Very fine stands of Riverine Forest occur along the upper reaches of the Anabranch and along the Murray River. Elsewhere they usually form a narrow band following the major streams. (Figure 11).

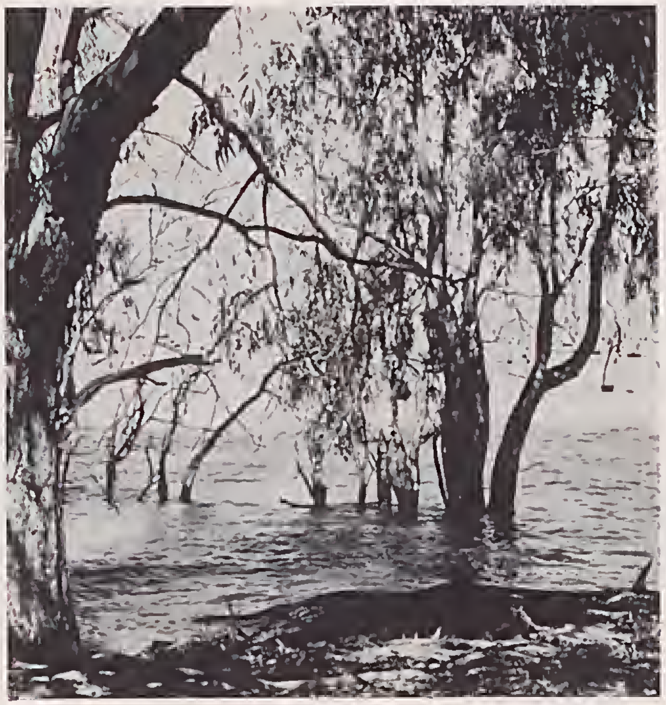

Figure 11. River Red Gum (*E. camaldulensis*) flooded by the Darling River near Pooncarie.

2. Black Box Woodland

Map units: 2 (11, 12, 15)
Code: eM2S
Structural formation: Low open-woodland
Height:10–20 m
Cover: 10–30% (Basal area 0.5 m^2ha^{-1})
Dominant species: *Eucalyptus largiflorens*
Understorey species: *Atriplex nummularia, Chenopodium nitrariaceum.*
Ground layer: *Osteocarpum acropterum* var. *deminutum, Boerhavia diffusa, Chamaesyce drummondii, Scleroblitum atriplicinum*
Species richness: (0.1 ha) 36.6 ± 3.0 (n=7)
Landform: Floodplains beyond major rivers and dry lake margins
Habitat (photopattern): Along creek lines and less dense than Riverine Forest
Soil: Heavy grey clay
Degradation/regeneration: Subject to periodic inundation, major regeneration occurs as floods subside. Most stands contain trees of similar size (age) and may represent past establishment patterns. The Black Box Woodlands are prime grazing country and the understorey is affected by this land use. In particular much of the previously extensive *Atriplex nummularia* stands that formed a shrub layer under and between the Black Box trees have now been lost. (Figure 12).

3. Dune Mallee

Map units: 3 (5, 6, 7)
Code: eS2H
Structural formation: Tall shrubland
Height: 2–10 m (function of time since fire)
Cover: 10–30% (Basal area 5m^2 ha^{-1})
Dominant species: *Eucalyptus socialis, E. costata, E. dumosa*
Understorey species: *Triodia irritans, Beyeria opaca, Podolepis capillaris, Chenopodium curvispicatum, Stipa nitida, Enchylaena tomentosa*
Species richness: (0.1 ha) 25.4 ± 0.8 (n= 5)
Landform: Longitudinal east-west dunes up to 10 m in height
Habitat (photopattern): Forms prominent small-grained photopattern
Soil: Calcareous red sand overlying grey clay
Degradation/regeneration: The dunes may become active with a wind-blown sandy surface if highly disturbed. Whereas the mallee eucalypts can resprout from lignotubers, *Triodia* is killed and new plants germinate soon after fire. Seedling eucalypts were rarely noted. Some areas of mallee have been cleared in the past. (Figure 13).

4. Arid Shrubland, Belah-Rosewood

Map units: 4 (5, 6, 7)
Code: cS2Z
Structural formation: Tall shrubland
Height: 8–12 m
Cover:10–30% (Basal area 2.5 m^2ha^{-1})
Dominant species: *Casuarina pauper, Alectryon oleifolius* subsp. *canescens.*
Understorey species: *Maireana pyramidata, Olearia pimeleoides, Enchylaena tomentosa, Sclerolaena* spp., *Aristida contorta.*

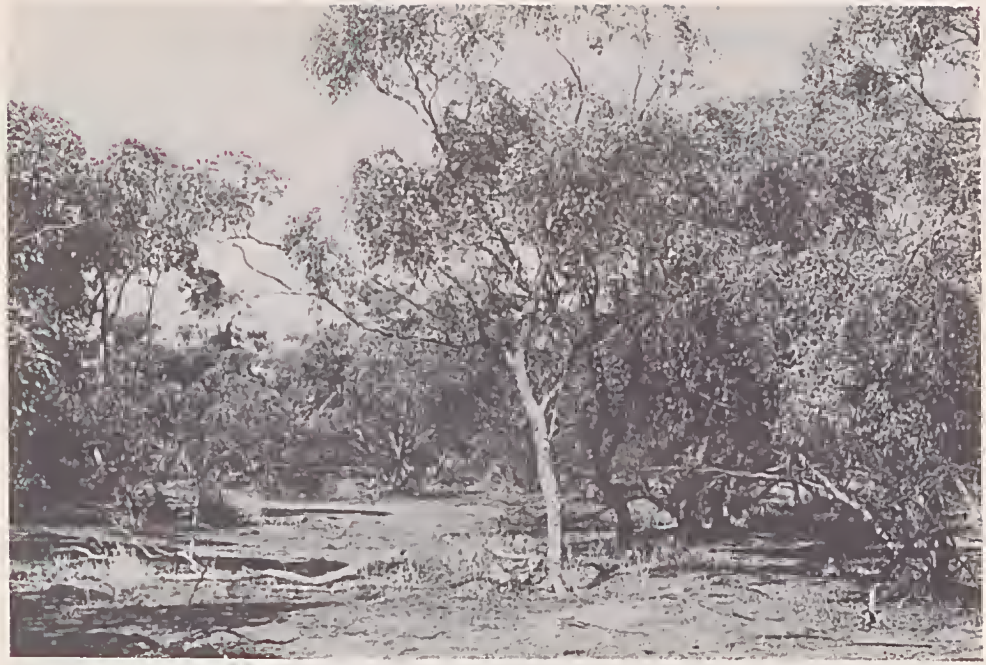

Figure 12. Black Box (*Eucalyptus largiflorens*) Woodland just south of Pooncarie on the Darling River.

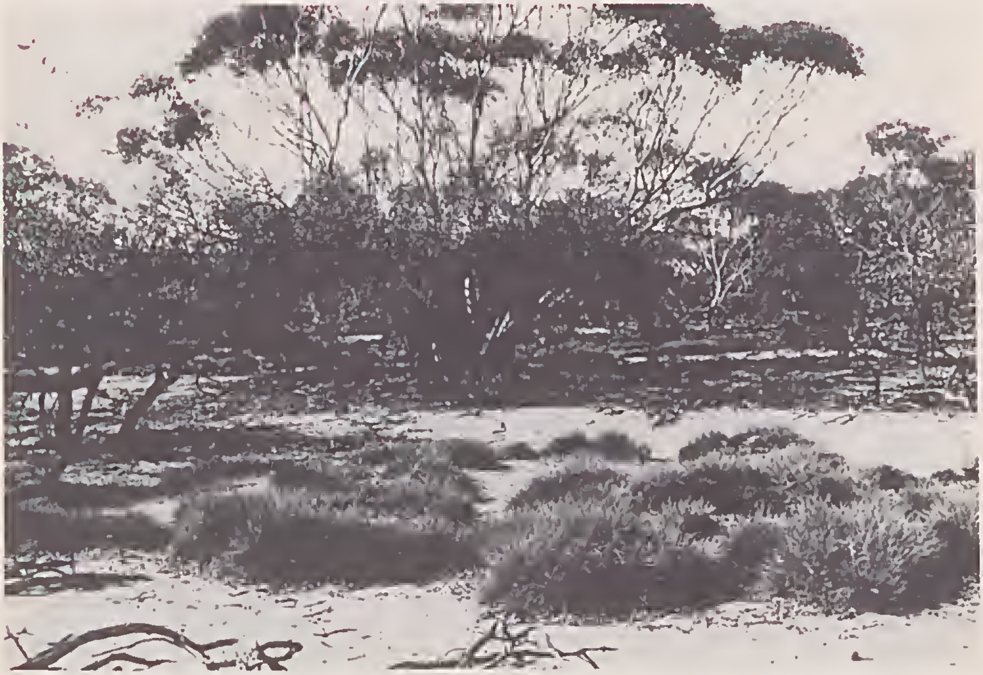

Figure 13. Dune Mallee with *Eucalyptus costata* and *Triodia irritans* on Nagaela homestead west of the Anabranch.

Species richness: (0.1 ha) 39.7 ± 4.6 (n= 6)
Landform: Raised areas of highly calcareous heavy soils with calcrete fragments
Habitat (photopattern): No dunes apparent and uniform mottled photopattern
Soil: Fine red sandy loam with calcrete nodules
Degradation/regeneration: Preferentially cleared because of its slightly better soil and because the dominant species do not resprout as readily as mallee does.The dominant species form clumps and this creates a mosaic pattern. *Alectryon* flowers irregularly and no seedlings were observed. Root suckers develop around parent plants but are highly palatable to sheep and rabbits and are kept grazed down. (Figure 14).

5. Arid Shrubland (mosaic of map unit 3 with 4)

Code: eS2H/cS2Z
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Dune Mallee (3) with Belah-Rosewood (4)
Habitat (photopattern): At least 70% of the area is dunefield but widely spaced with 4 in swales

6. Arid Shrubland (mosaic of map unit 4 with 3)

Code: cS2Z/eS2H
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3)
Habitat (photopattern): Finer grained photopattern than 5, predominately 4, may have some dunes with mallee but too small to map

7. Arid Shrubland (mosaic of map units 4, 3 & 8)

Code: cS2Z/eS2H/kZ2F
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3) and Black Bluebush (8)
Habitat (photopattern): Quite irregular, more patchy than 4 and with occasional open patches (8), each component too small to map separately

8. Black Bluebush

Map units: 8 (9, 10)
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, Rhagodia spinescens*
Understorey species: *Sclerolaena* spp., *Osteocarpum acropterum* var. *deminutum, Atriplex* spp.
Species richness: 35.4 ± 2.7 (n= 9)

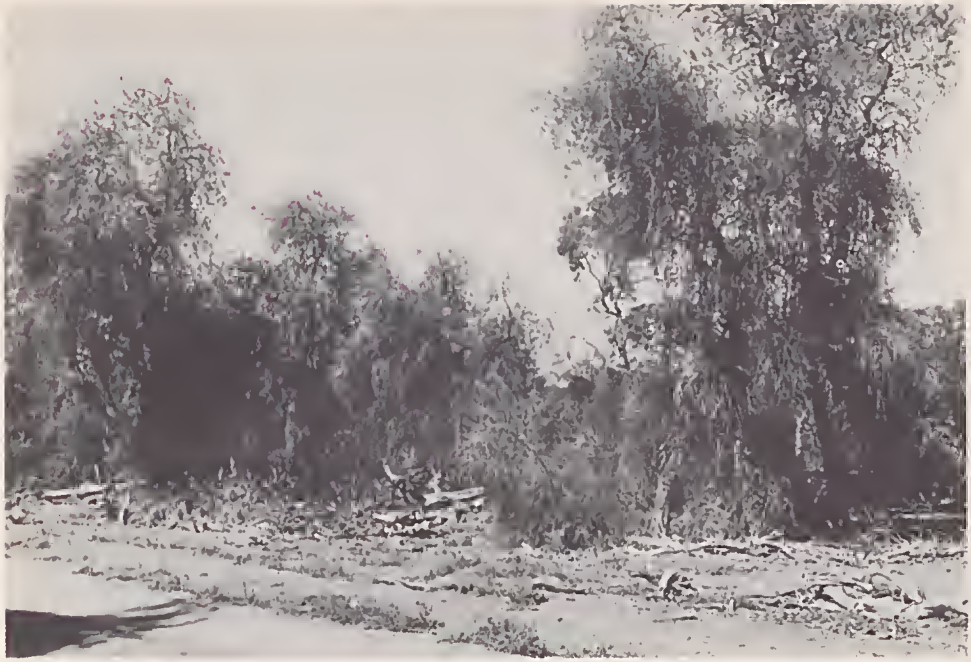

Figure 14. Stand of *Casuarina pauper*.

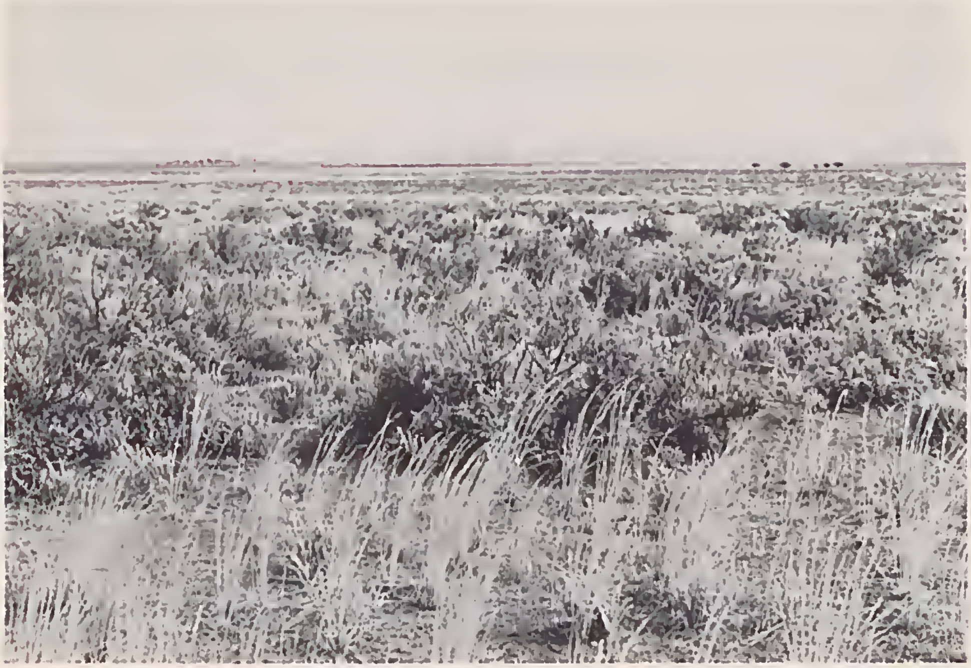

Figure 15. *Maireana pyramidata* shrubland on 'Nulla' homestead north of Lake Victoria.

Landform: Clay plain
Habitat (photopattern): Some scattered clumps of 4
Soil: Calcareous red loamy sand, red-brown loam, consistently with calcretions in top 40 cm
Degradation/regeneration: Under grazing no regeneration occurs. Sheep browse these perennial shrubs but goats and rabbits are more damaging, often ring-barking the main stems and excavating and eating the roots. Degraded areas may be invaded by *Nitraria billardieri*. (Figure 15).

9. Bluebush, Pearl Bluebush

Map unit: 9
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana sedifolia*
Understorey species: *Erodium* spp., *Tetragonia tetragonioides, Sclerolaena* spp.
Species richness: (0.1 ha) 24.7 ± 1.1 (n= 5)
Habitat (photopattern): More open than 8, some clumps of 4
Landform: Typically upslope of Black Bluebush on clay plain
Soil: Red sandy loam with nodules of calcrete in the top horizon
Degradation/regeneration: As for Black Bluebush. This shrubland also occurs with a mallee overstorey in restricted areas west of the Anabranch. (Figure 16).

10. Lunette Shrubland

Map unit: 10
Code: kZ2F
Structural formation: Low shrubland
Height: 0.8–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, M. appressa*
Understorey species: *Sclerolaena* spp., *Atriplex* spp.
Species richness: (0.1 ha) No estimate
Habitat (photopattern): Gypseous dunes associated with lakes, including lunettes
Landform: Gypseous dunes associated with lakes, including lunettes
Soil: Saline gypseous clay mantling sand core
Degradation/regeneration: These landforms can erode to create spectacular features such as the Walls of China at Lake Mungo. Such erosion usually follows periods of over-grazing and trampling. Few perennial plants persist on lunettes and no regeneration was observed. (Figure 17).

11. Bladder Saltbush

Map units: 11 (12, 15)
Code: kZ2F
Structural formation: Low shrubland
Height: 0.2–1 m
Cover: 10–30 %

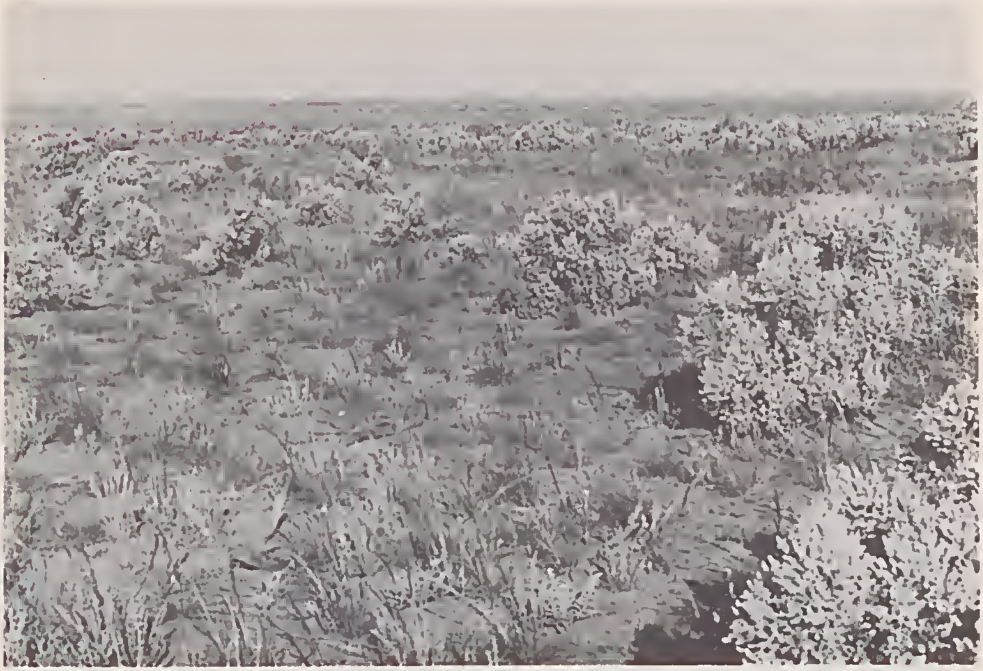

Figure 16. A stand of Bluebush (*Maireana sedifolia*) north-east of Lake Victoria.

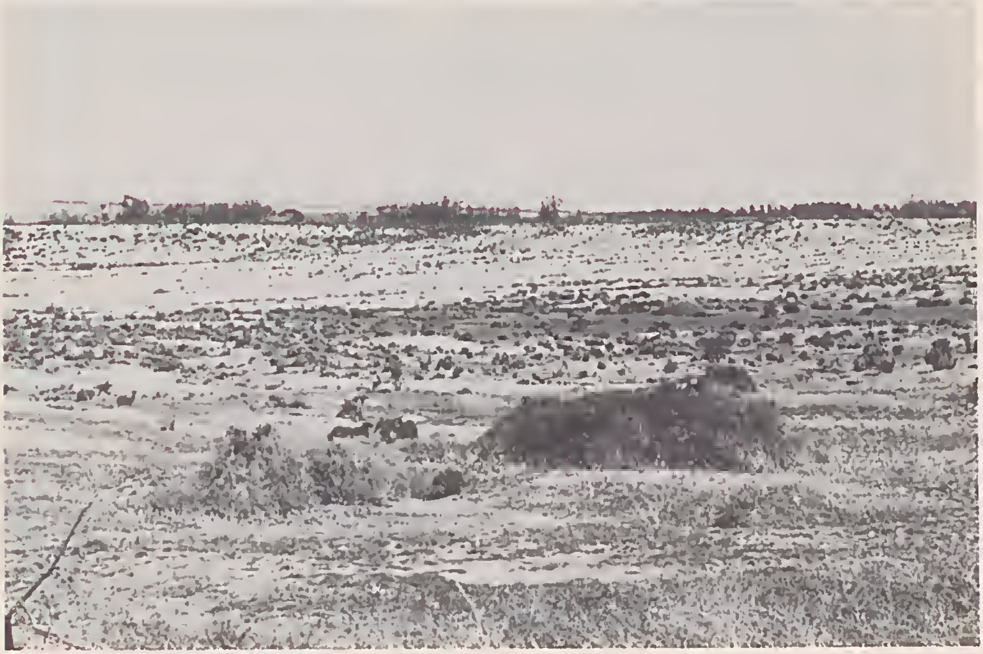

Figure 17. Lunette of Lake Victoria with scattered shrubs of *Maireana pyramidata.*

Dominant species: *Atriplex vesicaria*
Understorey species: *Sclerostegia tenuis, Pachycornia triandra, Osteocarpum acropterum* var. *deminutum, Disphyma clavellatum*
Species Richness: (0.1 ha) 18.1 ± 2.1 (n= 5)
Landform: Lower Alluvium, alluvial plains
Habitat (photopattern): Fine-grained, often with pronounced curvilinear patterns from paleochannels
Soil: Grey-brown clay loam, surface cracked
Degradation/regeneration: Often heavily grazed, affecting the shrub vitality and cover. No seedling regeneration was observed in the study area throughout the survey period. Degraded areas may be invaded by *Nitraria billardieri*. (Figure 18).

12. Pigface – Samphire

Map units: 12 (11, 15)
Code: kZ1F
Structural formation: Low open-shrubland.
Height: 0.1–0.4 m
Cover: <10%
Dominant species: *Disphyma clavellatum, Sclerostegia tenuis* [may have overstorey of *E. largiflorens*]
Understorey species: *Annual Atriplex, Sclerolaena* spp.
Species richness: No estimate
Landform: Saline flats
Habitat (photopattern): Associated with 15
Soil: Pale cream-grey cracking clay
Degradation/regeneration: It is generally considered that *Disphyma clavellatum* is now much reduced in abundance since settlement, due to grazing and trampling (Cunningham et al. 1981). This community may grade into saltpan. (Figure 19).

13. Canegrass Swamp

Map units: 13 (11, 15)
Code: yG3F
Structural formation: Grassland
Height: 1–3 m
Cover: 30–70 %
Dominant species: *Eragrostis australasica, Muehlenbeckia cunninghamii*
Understorey species: Usually absent
Species richness: (0.1 ha) No estimate
Landform: Depressions in clay plain
Habitat (photopattern): With scattered trees of *Eucalyptus largiflorens*
Soil: Grey cracking clay
Degradation/regeneration: Subject to intermittent flooding where water remains several months. May have scattered trees of *Eucalyptus largiflorens*. Important wildlife habitat particularly for nesting waterbirds, although it can also harbour feral pigs.

14. Sedge Swamp

Map unit: 14
Code: gG3F.

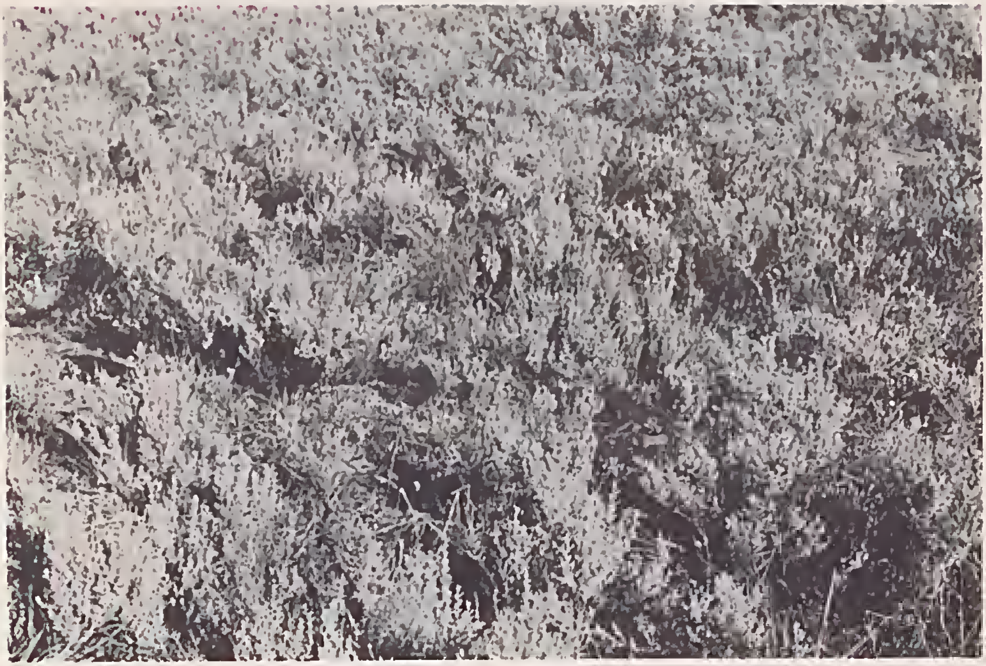

Figure 18. *Atriplex vesicaria* stand with *Sclerostegia tenuis* just west of Wentworth.

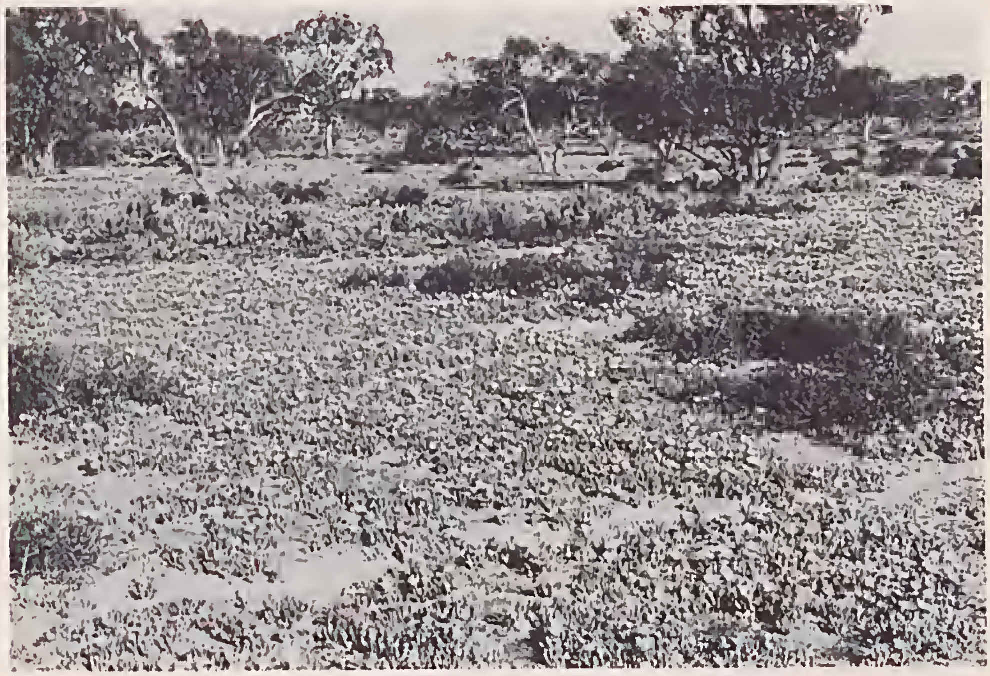

Figure 19. Pigface *Disphyma clavellatum* in flower with scattered plants of Samphire *Sclerostegia tenuis* with Black Box *Eucalyptus largiflorens.*

Structural formation: Sedgeland
Height: 0–0.5 m
Cover: 30–70 %
Dominant species: *Eleocharis pallens*
Understorey species: Usually absent
Species richness: (0.1 ha) No estimate
Landform: Flats or depressions within Riverine Forest, margins of swamps, claypans and lakebeds
Habitat (photopattern): Flats within RiverineForest
Soil: Variety of clay soil.
Degradation/regeneration: Responds quickly to rain and grows throughout the year if water is available. Only is grazed by stock if other more palatable species are unavailable.

15. Saltpan, Lakebed

Map units: 15, Lake
Code: kF2F
Structural formation: Open herbland
Height: 0–0.2 m
Cover: 10–30 %
Dominant species: *Sclerostegia tenuis, Muehlenbeckia cunninghamii, M. horrida* (edges)
Understorey species: *Atriplex leptocarpa, A. pseudocampanulata, Disphyma clavellatum*
Species richness: (0.1 ha) No estimate
Landform: Saltpan or clay flat often areas of groundwater discharge, some lakebeds
Habitat (photopattern): Saltpan or clay flat
Soil: Highly saline gypseous flats, fine-grained clay, large desiccation cracks
Degradation/regeneration: Many of the larger lakes are now cultivated and in such cases, all native vegetation has been destroyed. (Figure 20).

Plant communities too small to be shown as separate map units

Sand Plain Mallee

Map units: 3, 5, 6, 7
Code: eS2H
Structural formation: Tall shrubland
Height: 6–10 m
Cover:10–30 %
Dominant species: *Eucalyptus oleosa, E. socialis, E. gracilis*
Understorey species: *Chenopodium curvispicatum, Ptilotus exaltatus* var. *exaltatus, Olearia muelleri*
Species richness: (0.1 ha) 23.7 ± 1.1 (n= 5)
Landform: Sand plain, sand ridges
Soil: Calcareous sandy red earth, red duplex soil
Degradation/regeneration: More easily cleared than Dune Mallee because of flatter topography and heavier soil. No eucalypt seedling regeneration noted.

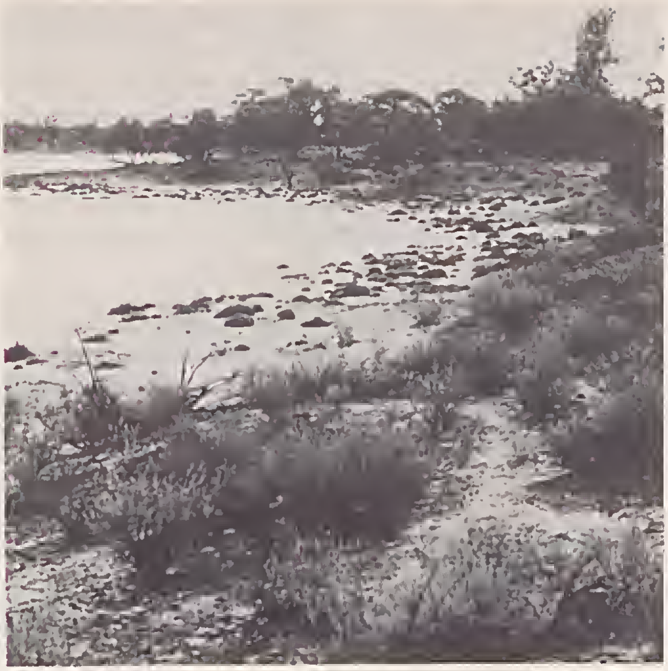

Figure 20. Edge of Salt Lake north of Lake Victoria with *Muehlenbeckia horrida* around margin.

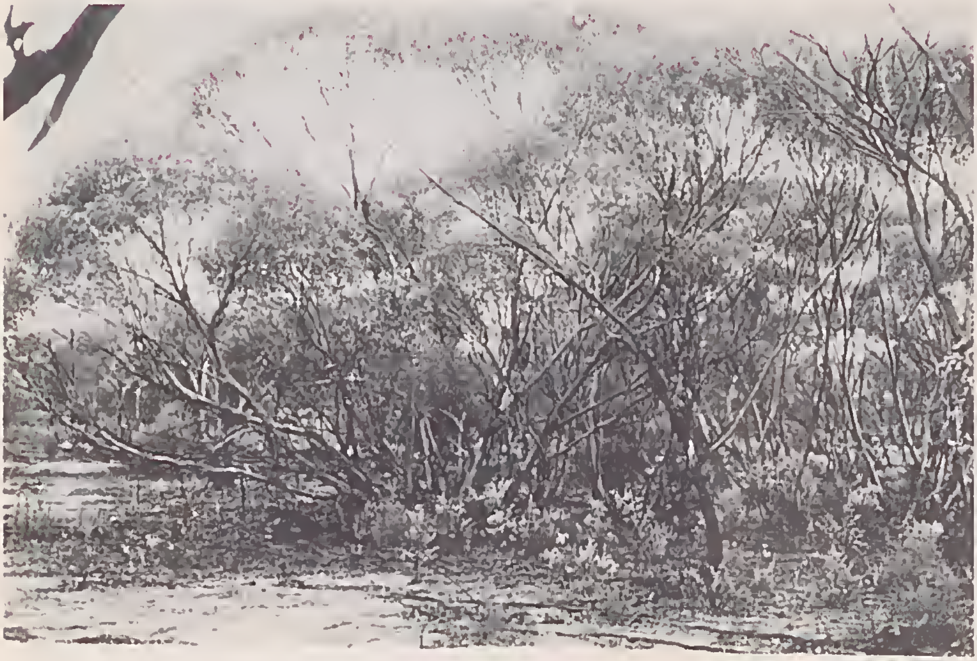

Figure 21. Swale mallee with *Eucalyptus gracilis* in flower.

Swale Mallee

Map units: 3, 5, 6, 7
Code: S2H
Structural formation: Tall shrubland
Height: 2–10 m
Cover: 10–30 %
Dominant species: *Eucalyptus gracilis, E. dumosa*
Understorey species: *Enchylaena tomentosa, Dissocarpus paradoxus, Senna artemisioides, Sclerolaena* spp.
Species richness: (0.1 ha) 34.2 ± 1.4 (= 5)
Landform: Swales between sand dunes and deflated sand plains
Soil: Calcareous red sand
Degradation/regeneration: More subject to clearing than the dune mallee. Often the sites for watering points and ground tanks and therefore prone to trampling and over-grazing. (Figure 21).

Mixed Woodland, Callitris Woodland

Map units: 4, 11
Code: pM2S
Structural formation: Open woodland
Height: 8–12 m
Cover: 10–30 %
Dominant species: *Callitris glaucophylla, Hakea leucoptera, Hakea tephrosperma, Myoporum platycarpum*
Understorey species: *Maireana pyramidata*
Species richness: no estimate
Landform: Sandy rises adjacent to riverine flats, source-bordering dunes
Soil: Deep loose sandy soil. On sandhills along the Murray and lowermost part of the Darling, Murray Pine, *Callitris preissii* subsp. *murrayensis* occurs and also much *C. preissii–C. glaucophylla* hybridisation (L.A.S. Johnson pers. comm.)
Degradation/regeneration: often cleared for valuable timber trees and only identifiable by the landform and scattered remnant trees. Further east of the mapped area this landform is often cultivated for wheat and other cereal crops. Similar woodland may be found on sandy rises on the western sides of lakes as well, for example west of Popiltah Lake. Such stands are always of small area and cannot be mapped at the scales employed here.

Acacia Shrubland

Map units: 1, 2, 4
Code: wS3F
Structural formation: Tall shrublan
Height: 2–6 m
Cover: 30–70%
Dominant species: *Acacia victoriae, Dodonaea, Acacia oswaldii*
Understorey species: *Sclerolaena* spp., *Maireana* spp.
Species richness: No estimate
Landform: Sandy rises such as source-bordering dunes which extend along rivers and major streams, creek beds and banks in a variety of landforms

Soil: Red sandy soil
Degradation/regeneration: Remnant trees of *Myoporum platycarpum*, *Hakea leucoptera*, *Hakea tephrosperma*, *Callitris glaucophylla* and *Callitris preissii* subsp. *murrayensis* may occur. This may represent highly disturbed areas that previously supported *Callitris* woodland. The dominant species may be mainly the 'woody weeds' which are invasive, colonising, native species.

Lignum Swamp

Map units: 2, 12, 14
Code: xS4F
Structural formation: Closed scrub
Height: 2–8 m
Cover: 70–100 %
Dominant species: *Muehlenbeckia cunninghamii* (*Eucalyptus camaldulensis*, *E. largiflorens* around edges)
Understorey species: Usually absent
Species richness: (0.1 ha) No estimate
Landform: Depressions with impounded water
Soil: Heavy clay
Degradation/regeneration: Very important wildlife habitat particularly for nesting waterbirds. Regenerates readily under favourable flood conditions. (Figure 23).

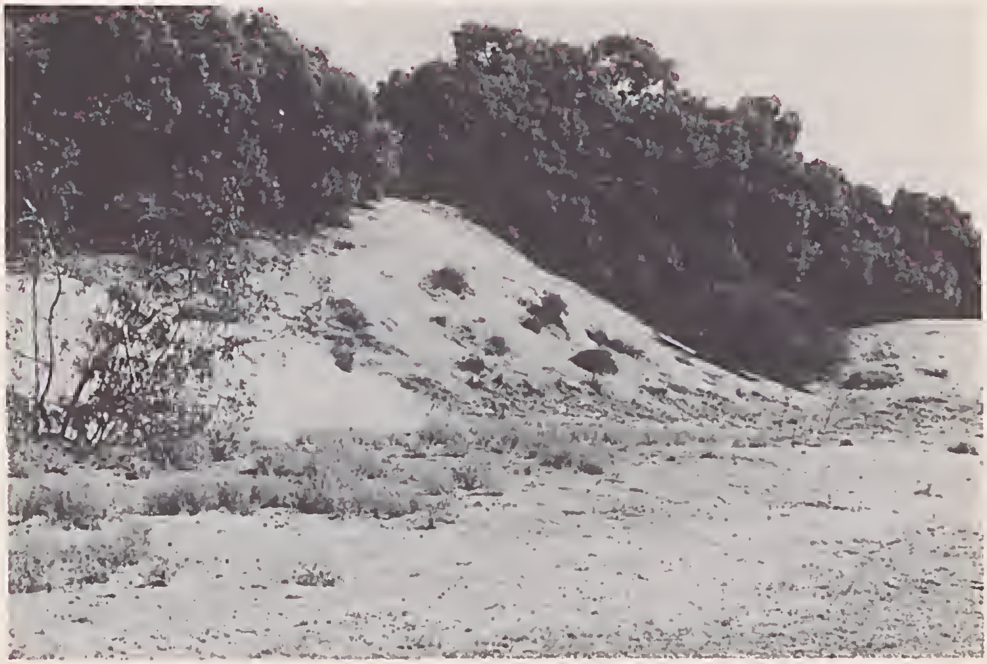

Figure 22. Acacia Shrubland on a source-bordering dune on the eastern bank of the Darling River northwest of Pooncarie.

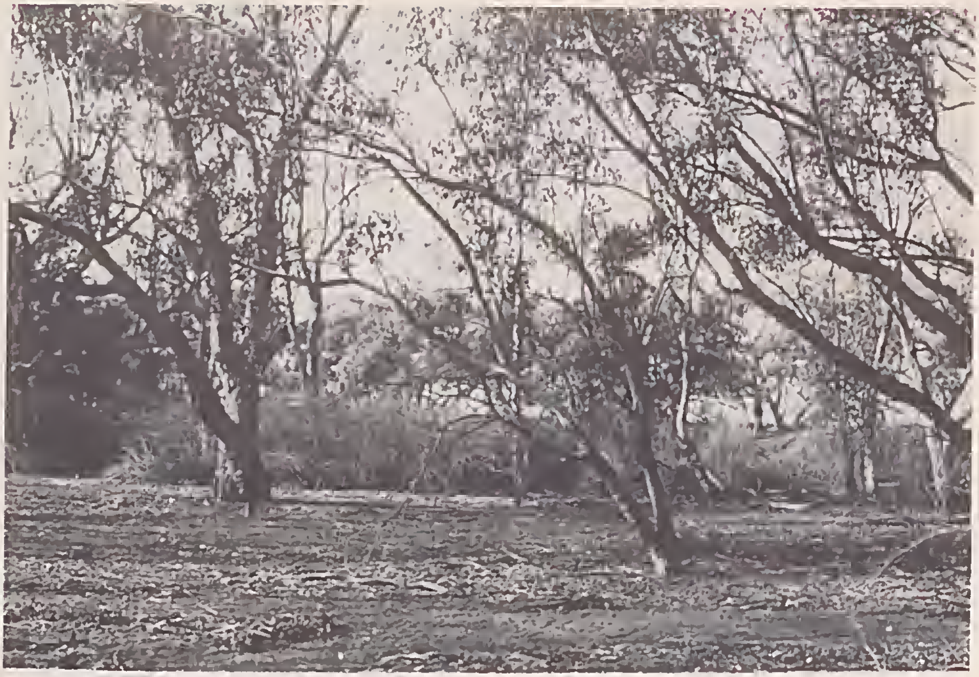

Figure 23. A small Lignum (*Muehlenbeckia cunninghamii*) swamp ringed by River Red Gums (*Eucalyptus camaldulensis*).

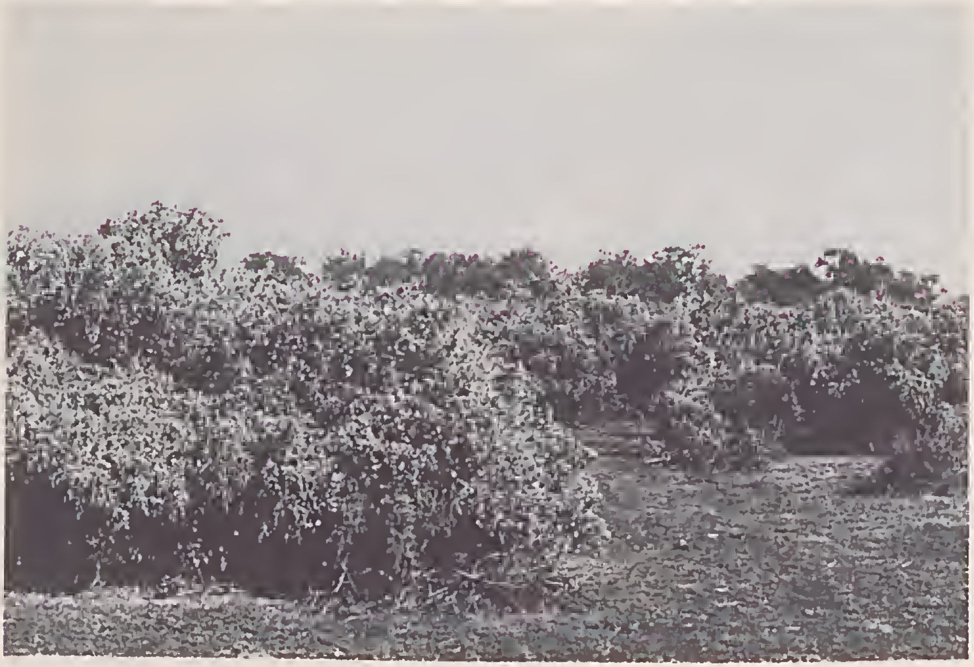

Figure 24. Stand of Old Man Saltbush (*Atriplex nummularia*) near the junction of the Darling and Murray rivers.

Old Man Saltbush

Map units: 2
Code: kS3F
Structural formation: Tall shrubland
Height: 1–2 m
Cover: 30–70 %
Dominant species: *Atriplex nummularia, Rhagodia spinescens,* [*Eucalyptus largiflorens*]
Understorey species: *Atriplex* spp., *Sclerolaena* spp.
Species richness: (0.1 ha) No estimate.
Landform: River flat
Soil: Clay soils
Degradation/regeneration: Grades into *Maireana pyramidata* shrubland away from the river. These deeply rooted shrubs can withstand severe drought and also tolerate flooding, but can be decimated by heavy continuous grazing. Only small relict stands remain of what were more extensive stands (Cunningham et al. 1981). (Figure 24).

Floristic composition

Appendix I contains the list of flowering plant species identified from sites or collections on the Ana Branch – Mildura map sheet area. The families are arranged alphabetically within orders, and genera alphabetically within families, and the species alphabetically within genera. An asterisk indicates an exotic species. Authorities are not given and can be found in Harden (1990), Jacobs & Lapinpuro (1986) or Jacobs & Pickard (1981).

Table 4 lists the floristic composition of broad vegetation categories for the mapped area. The table is modified from an earlier table (Fox 1984) which was based on a set of sites on the mapped area. The totals shown in the first column are the original site totals and in brackets the total recorded for all sites and collections for the map sheet. A total of 266 native species and exotic species were recorded for the map sheet area. This is 44% of the total expected for the Far South Western Plains (Table 1). The incidence of exotics, at 11% of the total, is relatively low compared to disturbed sites in the east (see Table 1, Fox & Fox 1986). The total species pool comes from 60 families of vascular plants however, ten families account for 86% of this richness. Principal among these are the Chenopodiaceae (78 species), Asteraceae (51 species) and Poaceae (40 species).

The total species data for the broad vegetation types in Table 4 indicate their relative richness. Mallee is markedly richer than the other types although it does not have proportionally more genera or families represented. Also these totals are composites from several sites. Single site collections for mallee can be quite low, depending on seasonal rainfall.

Table 4. Summary of floristic data from Ana Branch – Mildura map (from Fox 1984), with updated totals shown in the first column in brackets.

	Total		Mallee	Chenopod shrubland	Lakebed	Riverine forest	Casuarina woodland	Acacia shrubland
Species	188	(299)	96	55	44	37	33	30
Exotic	13	(33)	4	5	1	3	3	4
Genera	99	(191)	54	28	31	21	26	21
Spp./gen.	1.9	(1.6)	1.8	2	1.4	1.8	1.3	1.4
Families	37	(60)	27	10	13	10	15	14
Gen./fam.	2.7	(3.2)	2	2.8	2.4	2.1	1.7	1.5
Chenopodiaceae	62	(78, 26.3%)	26%	65.5%	43.2%	67.6%	33.0%	30.0%
Asteraceae	20	(51, 17.2%)	12.5	10.9	11.4	2.7	6.1	6.7
Fabaceae	19	(27, 9.1%)	11.5	5.5	4.6	8.1	12.1	20.0
Poaceae	19	(40, 13.5%)	9.4	9.1	11.4	2.7	12.1	6.7
Myrtaceae	10	(13, 4.4%)	6.3	-	6.8	5.4	-	3.3
Myoporaceae	5	(8, 2.7%)	5.2	-	-	-	3	3.3
Solanaceae	5	(8, 2.7%)	2.1	-	2.3	-	3	3.3
Amaranthaceae	4	(7, 2.4%)	3.1	-	2.3	-	-	-
Zygophyllaceae		(11, 3.7%)	-	-	-	-	-	-
Brassicaceae		(12, 4.0%)						
Sub-total	144	(255, 85.9%)	76.1	91.0	82.0	86.5	69.3	70.0

Modifications to the vegetation

Grazing

It was not within the scope of this study to incorporate a detailed investigation into the impact of grazing on the vegetation of the region. However, with grazing being the principal pastoral activity for much of the mapped area, it would be an oversight not to comment on observed impacts. Clearly there has been a deleterious impact on the vegetation of the region from the millions of both husbanded and feral animals that now graze and browse where once smaller nomadic populations of native grazers and browsers had limited impact. The provision of additional water supplies for the husbanded animals has also led to heightened populations of both feral and native animals through good and dry times. Perhaps most destructive of all has been the sustained high numbers of rabbits throughout the study area. Even in periods of drought, although their numbers are much reduced, foci of reinvasion persist and as soon as the country improves their numbers explode. Rabbits and goats are particularly destructive to native perennial plants because, as well as foliage, they eat bark and roots, commonly leading to the death of the plants.

In Kinchega National Park, north of the mapped area, the New South Wales National Parks and Wildlife Service conducted a long-term investigation of the interactions of kangaroos and sheep (Caughley, Shepherd & Short 1987). Within the National Park, large exclosures were maintained and the biomass and composition of the vegetation monitored. Similar plots were maintained on an adjacent property on Lake Tandou. Robertson (1987) found that in terms of biomass, extreme weather events overshadow the impact of grazing. There was no significant difference in composition between pasture grazed by kangaroos alone and by sheep and kangaroos, however trends may be blurred by the long history of sheep at all sites.

Fire

The usual fire frequency in arid and semi-arid rangelands is every 10 to 15 years (McArthur 1972). However, after years of above-average rainfall, fuel accumulates quickly. There have been several recorded extensive fires in western NSW, all following periods of above-average rainfall. Most of the mapped area showed no evidence of recent fire. East of the Darling there were extensive fires in 1974 but these did not spread west of the river. Recently there have been some experimental fires in the mallee west of the Anabranch of the Darling to promote the long-term survival of the mallee fowl.

Many species of plants in the region are resistant to fire, in that they have the ability to resprout. However, the important grass of much of the mallee country, *Triodia irritans,* is killed by fire and must regenerate from seed in the soil to persist at the site. CSIRO has had a long-term fire research program underway just east of Pooncarie (east of the mapped area) (Noble 1989).

Flooding and drought

Parts of the area, adjacent to the major streams, are subject to flooding from the major rivers. This has a direct impact on the vegetation, particularly on the River Red Gum forests and the Black Box woodlands. Recruitment of both dominant tree species only occurs in the conditions immediately after flooding.

The composition of the annual or short-lived perennial species in the ground layer is largely determined by the amount and seasonal distribution of rainfall (Fox in press). In drought years this stratum of the vegetation may be missing. With the onset of rain, seed stored in the soil germinates and quickly establishes a herbaceous ground layer. The composition of this herb stratum is determined by the duration and amount of rain in the season and the follow-up conditions. Most of the weed species found in the region are herbaceous plants that may dominate the ground stratum in good seasons.

Soil chemistry

Appendix II is modified from Table 2 in Fox (1984), it summarizes the chemical status of soil collected at a range of sites in the south-west of New South Wales, including sites on the Ana Branch – Mildura map sheet area. These give an indication of the regional trend in soil chemistry, related to broad vegetation types. Additional sites sampled subsequently on the map area are included in italics.

There is considerable variation in the chemical composition of all the soils sampled. In particular, the calcium content fluctuates widely. The vegetation types used in Appendix II are arranged in roughly increasing concentration of lime in the soil. Highest calcium content is found in the soil under Black Box, *Eucalyptus largiflorens,* however, it is also the most variable.

The soil pH is generally around neutrality (7.0), the most alkaline soil was that under *Alectryon* shrubland (mean 7.8 ± 0.2), and the most acidic soil was associated with *Callitris* woodland (5.96 ± 0.30).

Conservation of vegetation

As stated in the Introduction, there is only one nature reserve in the mapped area, that is Nearie Lake Nature Reserve, gazetted in 1973 and 4347 ha in area. There is also one national park and it extends onto part of the eastern edge of the Mildura sheet. This is Mallee Cliffs National Park, gazetted in 1977 with extensions in 1978 and 1983 to a total of 57,969 ha. North of the Ana Branch sheet is Kinchega National Park, first gazetted in 1967 with extensions in 1968, 1972, 1974 and1982, and totalling 44,182 ha in area. As a proportion of the mapped area the formal reservations (Nearie Lake and about one eighth of Mallee Cliffs National Park) represent less than 1% of the area. For the whole of the Western Division formal reserves (six national parks, eight nature reserves, two historic sites and one Aboriginal area) total over 760,000 ha. Recent acquisitions will bring the total to 940,000 ha, or almost 3% of the Western Division (Pressey & Nicholls 1991). This indicates the discrepancy between reserves in the north of the Division and the paucity of reserves in the south. East of the mapped area, and within the Western Division, is also Mungo National Park, but all of the other reserves are north of 33°S.

Pressey & Nicholls (1991) have considered the adequacy of the reserve system in north-western NSW. Using land systems maps, they estimated that nearly 6% of their study area (north-western NSW) was needed for at least one representation of each land system. Given that there are unique associations such as the Bladder Saltbrush (*Atriplex vesicaria*) with Samphire (*Sclerostegia tenuis*) found only in south-western NSW, which are currently not represented in the reserve system, there is an urgent need to identify and acquire suitable sites there.

Significant vegetation types

Although very widespread through much alluvial country of southern Australia, the woodlands of *Eucalyptus largiflorens* are of scientific interest because they comprise stands of single species of *Eucalyptus* trees. The usual pattern in most woodlands and forests dominated by eucalypts is for a mixture of at least two, and commonly more, species occurring together.

The mixed woodlands with species of *Callitris, Acacia, Hakea, Myoporum*, etc. that previously occurred on source-bordering dunes and other sandy rises, have been considerably reduced by clearing. In a landscape with very little good timber, these trees were a source of material for fence posts, sheds and houses.

The stands of *Atriplex nummularia* (Old Man Saltbush), either as understorey to *E. largiflorens* woodland or as tall shrublands, are now much reduced from their previous extent. However, some very fine stands occur at the junction of the Darling and the Murray Rivers. Their decline is in part a result of grazing, but also a consequence of a past clearing program because they harbour rabbits. Isolated individual shrubs are testament to their previous wider distribution.

The low shrubland of *Atriplex vesicaria* with *Sclerostegia tenuis* and *Pachycornia triandra* is particularly well developed on the lower alluvium west of Wentworth. It is not represented in any conservation reserve.

Rare species

Table 5 lists the species from the Far South West Plains that are considered rare or endangered (Leigh et al. 1981, Briggs & Leigh 1988). Recently the restricted species of the Western Division have been reexamined (Pressey, Cohn & Porter 1990), and their Category and Priority classes are also given in Table 5.

Table 5. Species of flowering plants, occurring in the Far South Western Plains, and listed as being rare or endangered by Briggs & Leigh (1988). Those in square brackets were listed by Leigh, et al. 1981), the Risk Codes[1] are as follows: 2 maximum geographic range of 100 km, 3 range over 100 km but restricted to highly specific habitats, X Presumed extinct, E Endangered species in serious risk of disappearing, V Vulnerable species, at risk over a longer period; R Rare species, not currently considered endangered or vulnerable; C Species known to be represented within a National Park or other proclaimed reserve; a adequately reserved; - adequacy of reservation unknown; and [2] Category and Priority according to Pressey et al. (1990).

Family	**Species**	**Risk Code[1]**	**Category[2]**	**Priority[2]**
Asteraceae	*Acanthocladium dockeri*	3X	3A(X)	2
Chenopodiaceae	*Atriplex papillata*	[3RC]	3A	3
Eriocaulaceae	*Eriocaulon australasicum*	2VCa		
Fabaceae (Faboideae)	*Swainsona laxa*	3VCa	3A	2
Gyrostemonaceae	*Codonocarpus pyramidalis*	3RC-	3A(X)	2
Fabaceae (Mimosoideae)	*Acacia carnei*	3RC-	3A	2
	Acacia rivalis	[3RC]	3A	3

The Categories recognised by Pressey et al. (1990) combine both the species geographic range and the status of its populations. 3A is 'restricted distribution in the Western Division and also occurring interstate, with small range and/or few records interstate'. (X) is presumed extinct in the Western Division.

Acanthocladium dockeri (Spiny Everlasting) is a small rigid shrub only collected during the last century from sandhills near the lower Darling River, it is probably extinct. *Atriplex papillata* is a prostrate forb. The few collections of this species are from the extreme south-west of the South Western Plains (not FSWP as previously thought) where it occurs around the margins of salt lakes. *Eriocaulon australasicum* (Pipewort) is a small annual forb known only from one collection in 1853 from near Balranald, east of the mapped area. *Swainsona laxa* (Yellow Darling Pea) has been recorded from Menindee, north of the mapped area and from Euston, just east of the mapped area on the Murray River. It has also been collected from Mount Hope in central NSW *Codonocarpus pyramidalis* (Native Poplar) is a tall shrub or small tree. It was collected from the Pooncarie district, just east of the mapped area, earlier this century and has not been recorded since. Both species of *Acacia*, *A. carnei* and *A. rivalis* are from near Broken Hill, to the north of the mapped area.

Conclusions

The far southwest of New South Wales, covered by the Ana Branch – Mildura vegetation map, is an alluvial landscape with relatively few plant communities. Some communities are restricted to either aeolian, fluvial or lacustrine landforms but there is considerable sharing of species. Fifteen map units were recognised but some communities were unmappable because their small areal extent precludes them from representation at this scale.

The vegetation of western New South Wales is relatively poorly conserved in reserves compared with that of the eastern portion of the state, and the southwest is not as well served by vegetation reserves as the north. Of the area mapped less than one percent is in a conservation reserve. This is in spite of several significant vegetation types and the more pervasive need to conserve representative samples of all our vegetation types before they are too degraded by the combined assaults of domestic and feral animals.

Acknowledgments

The work described in this paper was begun in 1979 with the able assistance of Heidi Dlugaj. Heidi Fallding accompanied the author on several field trips and methodically collated the floristic records. Georgi Legoe, Michael Doherty, Penny Farrant and Gwen Harden assisted with some of the field sampling. Liz Norris maintained the field data and floristic records as well as assisting in the field. The figures were drafted by Jenny Collins. Prints were made by Marianne Porteners. I wish to sincerely thank the botanists of the National Herbarium of New South Wales for their identifications of many plant specimens. Soil chemical analyses were conducted by the Department of Agriculture. The Australian Biological Resources Survey provided funds for additional field trips in the early stages of the project, and is gratefully acknowledged. Lastly many thanks to the lease-holders who allowed access to their land and provided much needed local knowledge.

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APPENDIX I

Flowering plants recorded from the Ana Branch – Mildura map sheet area. Names are those currently in use by the National Herbarium of New South Wales and authorities are given in Harden (1990), Jacobs & Lapinpuro (1986) or Jacobs & Pickard (1981) except as given in the text.

GYMNOSPERMS

CUPRESSACEAE
Callitris glaucophylla
Callitris preissii subsp. *verrucosa*
Callitris preissii subsp. *murrayensis*

ANGIOSPERMS – DICOTYLEDONS

AIZOACEAE
Disphyma clavellatum
Mesembryanthemum nodiflorum
Mollugo cerviana
**Psilocaulon tenue*
Sarcozona praecox
Tetragonia tetragonoides
Tranthema triquetra
Zaleya galericulata subsp. *galericulata*

AMARANTHACEAE
Alternanthera denticulata
Amaranthus grandiflorus
Amaranthus macrocarpus
Ptilotus exaltatus var. *exaltatus*
Ptilotus obovatus
Ptilotus polystachyus
Ptilotus seminudus

APIACEAE
Daucus glochidiatus

ASCLEPIADACEAE
Leichhardtia australis

ASTERACEAE
Actinobole uliginosum
Angianthus tomentosus
Brachycome ciliaris var. *ciliaris*
Brachycome ciliaris var. *lanuginosa*
Brachycome heterodonta var. *heterodonta*
Brachycome lineariloba
**Calendula arvensis*
Calocephalus sonderi
Calotis cuneifolia
Calotis cymbacantha
Calotis hispidula
**Carthamus tinctorius*
**Centaurea melitensis*
Centipeda cunninghamii
Centipeda thespedioides
Chthonocephalus pseudevax
Craspedia pleiocephala
Craspedia uniflora
**Dittrichia graveolens*
Eriochlamys behrii
Gnaphalium sphaericum
Helichrysum semipapposum
Helipterum corymbifolium
Helipterum floribundum
Helipterum jessenii
Helipterum moschatum
Helipterum pygmaeum
Helipterum uniflorum
**Hypochoeris glabra*
Isoetopsis graminifolia
Ixiolaena leptolepis
Millotia greevesii subsp. *greevesii* var. *greevesii*
Minuria cunninghamii
Myriocephalus stuartii
Olearia muelleri
Olearia pimeleoides var. *pimeleoides*
Olearia subspicata
**Onopordum acanthium*
**Onopordum acaulon*
Podolepis capillaris
Rutidosis helichrysoides
Senecio glossanthus
Senecio gregorii
Senecio quadridentatus
**Sonchus asper*
**Sonchus oleraceus*
Toxanthes perpusilla
Vittadinia triloba/cuneata complex
Vittadinia cuneata subsp. *cuneata* f. *cuneata*
Vittadinia cuneata var. *morrisii*
Waitzia acuminata
**Xanthium occidentale*

BORAGINACEAE
**Echium plantagineum*
Halgania cyanea
Heliotropium curassavicum
Heliotropium supinum
Omphalolappula concava
Plagiobothrys plurisepaleus

BRASSICACEAE
**Alyssum linifolium*
Arabidella nasturtium
Arabidella trisecta
Blennodia canescens
**Brassica tournefortii*

*Carrichtera annua
Geococcus pusillus
Harmsiodoxa blennodiodes
Lepidium phlebopetalum
Phlegmatospermum cochlearinum
*Sisymbrium erysimoides
Stenopetalum lineare

CACTACEAE
*Opuntia paraguayensis

CAMPANULACEAE
Wahlenbergia fluminalis
Wahlenbergia gracilenta
Wahlenbergia tumidifructa

CAPPARIDACEAE
Apophyllum anomalum

CARYOPHYLLACEAE
Scleranthus minusculus
*Spergularia rubra
Stellaria angustifolia

CASUARINACEAE
Casuarina pauper

CHENOPODIACEAE
Atriplex acutiloba
Atriplex angulata
Atriplex conduplicata
Atriplex eardleyae
Atriplex holocarpa
Atriplex leptocarpa
Atriplex limbata
Atriplex lindleyi
Atriplex nummularia
Atriplex pseudocampanulata
Atriplex pumilio
Atriplex semibaccata
Atriplex spongiosa
Atriplex stipitata
Atriplex suberecta
Atriplex velutinella
Atriplex vesicaria subsp. *calcicola*
Atriplex vesicaria subsp. *vesicaria*
Chenopodium cristatum
Chenopodium curvispicatum
Chenopodium desertorum subsp. *anidiophyllum*
Chenopodium desertorum subsp. *desertorum*
Chenopodium desertorum subsp. *microphyllum*
Chenopodium nitrariaceum
Chenopodium pumilio
Dissocarpus biflorus var. *biflorus*
Dissocarpus paradoxus
Dysphania glomulifera
Einadia hastata
Einadia nutans subsp. *nutans*
Enchylaena tomentosa
Halosarcia pergranulata subsp. *divaricata*
Maireana appressa
Maireana brevifolia
Maireana ciliata
Maireana coronata
Maireana decalvans
Maireana erioclada
Maireana georgei
Maireana microphylla
Maireana pentagona
Maireana pentatropis
Maireana pyramidata
Maireana radiata
Maireana schistocarpa
Maireana sclerolaenoides
Maireana sedifolia
Maireana trichoptera
Maireana triptera
Maireana turbinata
Malacocera tricornis
Osteocarpum acropterum var. *deminutum*
Pachycornia triandra
Rhagodia spinescens
Rhagodia ulicina
Salsola kali var. *kali*
Scleroblitum atriplicinum
Sclerolaena bicornis
Sclerolaena brachyptera
Sclerolaena calcarata
Sclerolaena decurrens
Sclerolaena diacantha
Sclerolaena divaricata
Sclerolaena intricata
Sclerolaena muricata var. *muricata*
Sclerolaena muricata var. *villosa*
Sclerolaena obliquicuspis
Sclerolaena parviflora
Sclerolaena patenticuspis
Sclerolaena stelligera
Sclerolaena tricuspis
Sclerolaena ventricosa
Sclerolaena stelligera
Sclerostegia tenuis
Threlkeldia proceriflora

CHLOANTHACEAE
Dicrastylis verticillata

CONVOLVULACEAE
*Convolvulus arvensis
Convolvulus erubescens

CRASSULACAEAE
Crassula colorata var. *acuminata*
Crassula peduncularis
Crassula sieberiana subsp. *tetramera*

CUCURBITACEAE
*_Cucumis myriocarpus_
Zehneria micrantha

EUPHORBIACEAE
Bertya cunninghamii
Beyeria opaca
Chamaesyce drummondii
Phyllanthus lacunarius

FABACEAE – Caesalpinoideae
Senna artemisioides nothosubsp. _coriacea_
Senna artemisioides subsp._filifolia_
Senna artemisioides subsp. _petiolaris_

FABACEAE–Faboideae
Eutaxia microphylla var. _microphylla_
Glycyrrhiza acanthocarpa
Lotus cruentus
*_Medicago minima_
*_Medicago polymorpha_
Psoralea patens group.
Swainsona microphylla
Swainsona phacoides subsp. _phacoides_
Templetonia egena

FABACEAE–Mimosoideae
Acacia aneura
Acacia bivenosa subsp. _wayi_
Acacia brachystachya
Acacia burkittii
Acacia colletioides
Acacia havilandiorum
Acacia jennerae
Acacia ligulata
Acacia loderi
Acacia nyssophylla
Acacia oswaldii
Acacia stenophylla
Acacia wilhelmiana
Acacia tetragonophylla
Acacia victoriae

FRANKENIACEAE
Frankenia foliosa

GERANIACEAE
Erodium cicutarium
Erodium crinitum

GOODENIACEAE
Goodenia cycloptera
Goodenia fascicularis
Goodenia pinnatifida
Goodenia pusilliflora
Scaevola spinescens

GYROSTEMONACEAE
Codonocarpus cotinifolius

HALORAGACEAE
Haloragis glauca

LAMIACEAE
Mentha australis
*_Salvia verbenaca_
Teucrium racemosum
Westringia rigida

LORANTHACEAE
Amyema linophyllum subsp. _orientale_
Amyema miquellii
Amyema preissii
Lysiana exocarpi subsp. _diamantinensis_

MALVACEAE
Abutilon otocarpum
Lawrencia glomerata
Radyera farragei
Sida ammophila
Sida filiformis
Sida intricata
*_Sida rhombifolia_

MYOPORACEAE
Eremophila glabra
Eremophila latrobei
Eremophila maculata
Eremophila oppositifolia
Eremophila polyclada
Eremophila scoparia
Eremophila sturtii
Myoporum platycarpum

MYRTACEAE
Eucalyptus camaldulensis
Eucalyptus dumosa
Eucalyptus leptophylla
Eucalyptus gracilis
Eucalyptus largiflorens
Eucalyptus largiflorens x _E. populnea_ subsp. _bimbil_
Eucalyptus costata
Eucalyptus incrassata
Eucalyptus oleosa
Eucalyptus oleosa x _E. socialis_
Eucalyptus populnea subsp. _bimbil_
Eucalyptus porosa
Eucalyptus socialis
Melaleuca lanceolata

NYCTAGINACEAE
Boerhavia coccinea
Boerhavia dominii

OXALIDACEAE
Oxalis perennans

PITTOSPORACEAE
Pittosporum phillyreoides

PLANTAGINACEAE
Plantago cunninghamii
Plantago drummondii
Plantago turrifera

PLUMBAGINACEAE
**Limonium lobatum*

POLYGONACEAE
**Emex australis*
Muehlenbeckia cunninghamii
Muehlenbeckia florulenta
Muehlenbeckia diclina
Muehlenbeckia horrida
**Rumex crystallinus*
Rumex tenax

PORTULACACEAE
Calandrinia eremaea
Calandrinia pumila
Calandrinia volubilis
Portulaca intraterranea
Potulaca oleracea

PROTEACEAE
Grevillea huegelii
Hakea leucoptera
Hakea tephrosperma

RANUNCULACEAE
Myosurus minimus
Ranunculus pentandrus var. *platycarpus*
Ranunculus pumilio

RHAMNACEAE
Cryptandra amara var. *longiflora*

RUTACEAE
Geijera parviflora

SANTALACEAE
Exocarpos aphyllus
Santalum acuminatum

SAPINDACEAE
Alectryon oleifolius subsp. *canescens*
[formerly *Heterodendrum*]
Atalaya hemiglauca
Dodonaea attenuata
Dodonaea bursariifolia
Dodonaea cuneata
Dodonaea triquetra
Dodonaea viscosa subsp. *angustissima*

SCROPHULARIACEAE
Morgania floribunda

SOLANACEAE
Duboisia hopwoodii
Lycium australe
**Nicotiana glauca*
Nicotiana simulans
Nicotiana velutina
Solanum coactiliferum
Solanum esuriale
Solanum nigrum

THYMELAEACEAE
Pimelea microcephala subsp. *microcephala*
Pimelea pauciflora
Pimelea trichostachya

URTICACEAE
Parietaria debilis

VERBENACEAE
**Phyla nodiflora*
**Verbena supina*

ZYGOPHYLLACEAE
Nitraria billardieri
Tribulus terrestris
Zygophyllum ammophillum
Zygophyllum apiculatum
Zygophyllum aurantiaceum
Zygophyllum glaucum
Zygophyllum eremaeum
Zygophyllum iodocarpum
Zygophyllum ovatum
Zygophyllum paradoxa
Zygophyllum simile

ANGIOSPERMS – MONOCOTYLEDONS

AMARYLLIDACEAE
Crinum flaccidum

ANTHERICACEAE
Thysanotus baveri

ASPHODELACEAE
Bulbine alata
Bulbine semibarbata

CYPERACEAE
Bulboschoenus medianus
Cyperus exaltatus
Cyperus gymnocaulos

JUNCACEAE
**Juncus acutus*

JUNCAGINACEAE
Triglochin calcitrapa

LOMANDRACEAE
Lomandra effusa

POACEAE
Agrostis avenacea
Amphipogon caricinus var. *caricinus*
Aristida contorta
Bromus arenarius
**Bromus rubens*
Chloris divaricata
Chloris truncata
Dactyloctenium radulans
Danthonia caespitosa
Danthonia eriantha
Diplachne fusca
Enneapogon avenaceus
Enneapogon nigricans
Enneapogon polyphyllus
Enteropogon acicularis
Eragrostis australasica
Eragrostis dielsii var. *pritzelii*
Eragrostis parviflora
Eriochloa crebra
Eriochloa pseudoacritricha
**Hordeum leporinum*
**Lamarckia aurea*
Paspalidium jubiflorum
Rostraria pumila
**Schismus barbatus*
Stipa elegantissima
Stipa mollis
Stipa nitida
Stipa nodosa
Stipa platychaeta
Sporobolus mitchellii
Tragus australianus
Triodia irritans
Tripogon loliiformis
Triraphis mollis
**Vulpia bromoides*
**Vulpia myuros*
Zygochloa paradoxa

TYPHACEAE
Typha domingensis

APPENDIX II

Summary of cation content, electrical conductivity and pH of vegetation sites. Exchangeable cations (Ca, Mg, K and Na) are expressed as m.e./100g, electrical conductivity (E.C.) is based on 1:2 mS/cm (modified from Fox 1984). Entries in *italics* are for sites sampled since 1984 on the map area. (mean ± s.e.)

Veg. Type	**n**	**Ca**	**Mg**	**K**	**Na**	**Ca/ Total Cations**	**E.C.**	**pH (CaCl$_2$)**
Mallee - Triodia	5 *5*	3.0±0.5 *3.0+0.5*	0.6±0.1 *0.6+0.1*	0.3±0.1 *0.3+0.1*	0.01±0 *0.01+0*	0.8±0.02 *0.8+0.02*	0.05±0.01 *0.05+0.01*	6.84±0.333 *6.8±0.33*
***Callitris* woodland**	5 -	4.2±0.4 -	0.9±0.2 -	0.6±0.1 -	0.02±0.01 -	0.8±0.03 -	0.04±0.01 -	5.96±0.300 -
***Alectryon* shrubland**	5 *5*	5.6±1.5 *5.6+1.5*	1.2±0.3 *1.2+0.3*	0.8±0.1 *0.8+0.1*	0.02±0.01 *0.02+0.01*	0.7±0.01 *0.7+0.01*	0.07±0.02 *0.07+0.02*	7.8±0.2 *7.8+0.2*
***Dodonaea* shrubland**	2 *2*	5.8±1.8 *5.8+1.8*	0.8±0.04 *0.8+0.04*	0.6±0.1 *0.6+0.1*	0.01±0 *0.01+0*	0.8±0.1 *0.8+0.1*	0.11±0.03 *0.11+0.03*	7.65±0.155 *7.65+0.2*
***Maireana* shrubland**	17 *5*	7.5±1.2 *8.8+1.3*	2.3±0.3 *2.5+0.7*	1.1±0.1 *1.3+0.2*	0.3±0.1 *0.4+0.2*	0.6±0.02 *0.7+0.04*	0.11±0.01 *0.13+0.01*	6.59±0.299 *7.4+0.27*
***Casuarina* woodland**	14 *5*	9.0±1.6 *2.8+0.1*	3.2±0.6 *1.3+0.1*	1.0±0.1 *0.7+0.1*	0.3±0.1 *0.1+0.1*	0.7±0.03 *0.6+0.02*	0.15±0.03 *0.05+0.01*	6.97±0.122 *7.0+0.09*
***A. vesicaria* shrubland**	8 *4*	9.7±0.5 *10.1+2.5*	8.2±1.5 *10.4+3.5*	1.6±0.2 *1.6+0.4*	1.7±0.5 *2.0+1.2*	0.5±0.03 *0.5+0.08*	0.66±0.29 *0.88+0.6*	5.98±0.377 *7.0+0.21*
Mallee - chenopod	14 *5*	11.2±2.3 *7.0+2.1*	2.5±0.3 *1.4+0.3*	0.8±0.1 *0.5+0.1*	0.1±0.03 *0.1+0.1*	0.7±0.03 *0.7+0.04*	0.11±0.02 *0.09+0.03*	6.94±0.244 *7.04+0.3*
Black Box woodland	20 *5*	13.7±1.2 *19.8+1.7*	7.5±0.9 *13.5+0.5*	1.5±0.2 *2.7+0.2*	0.9±0.2 *1.9+0.2*	0.6±0.02 *0.5+0.03*	0.22±0.03 *0.37+0.03*	6.02±0.200 *7.2+0.22*

Manuscript received 27 February 1991

Manuscript accepted 3 July 1991

SHORT COMMUNICATION

New findings of the rare tree *Syzygium paniculatum* (Myrtaceae) in the Wyong area, New South Wales

Introduction

Syzygium paniculatum Gaern. (Brush Cherry or Magenta Lilly Pilly) has only been known from a few isolated localities along the New South Wales coastline between Jervis Bay and Myall Lakes (Hyland 1983). Collections from Bulahdelah, Gosford, Towra Point and St Georges Basin have been recorded (National Herbarium of NSW. It has been found in remnant littoral rainforests, generally in low population numbers.

The species is coded 3ECi by Briggs & Leigh (1988), indicating that it is inadequately conserved in national parks or nature reserves and is regarded as being endangered, with a serious risk of disappearing from the wild within one or two decades. This paper reports recently discovered populations in the Wyong area on the Central Coast and provides basic data on the vegetation and ecology which may contribute towards a management program for the species.

Locations

Following fieldwork in 1989, further populations have been identified (Figure 1). The first population (Site A) is to be found on the North Entrance Peninsula (151°31′10″E 33°18′30″S). It occurs as a narrow linear band along the slope of an east facing sand dune which was left undisturbed during previous sand mining operations. The population appears to number at least fifty trees on the eastern side of the main road with at least twenty trees thought to be present on the western side. The latter has not been field verified. They lie outside the littoral rainforest site No. 171a conserved by State Environment Planning Policy No. 26.

Site B is a small population adjacent to but outside the southern boundary of the Munmorah State Recreation Area (151°34′30″E 33°13′50″S). It lies at the base of a west facing sand dune. Further sporadically distributed individuals have been located around Lake Munmorah nearby.

Site C is along the banks of Ourimbah Creek and may possibly prove to be the largest population. At this stage at least forty trees have been located between the valley's upper and lower reaches (151°20′30″E 33°21′00″S - 151°16′30″E 33°18′30″S). Some trees are large, with one specimen having a diameter (dbh) of nearly 1 metre. Ourimbah Creek is sinuous and private property prohibits further investigation. The survey was confined to the point where Ourimbah Creek and Ourimbah Creek Valley Road meet. Thus, although the trees have been found all along the creek and on the flood plain downstream as far as the Pacific Highway, the full extent of the population remains unknown.

Habitat

Hyland (1983) states that the species is known from 'sandy soil or on stabilised sand dunes in coastal areas'. This description aptly describes their habitat in the Wyong area.

Site A on the North Entrance Peninsula is on Quaternary coastal sand dunes comprising deep medium grained quartz sands with shallow podsol development. Although recontouring of the dune system after sand mining has occurred immediately east of the populations location, they appear to occupy a mid slope position. As far as can be ascertained, because of infestation with *Lantana camara* and *Chrysanthemoides monilifera*, the population is in littoral rainforest. Associated species include *Ficus fraseri, Elaeocarpus obovatus, Acmena smithii* and *Rhodomyrtus psidioides.*

Site B is similar except that it is located at the base of a sand dune where ponded conditions can occur. Adjacent vegetation is remnant swamp forest of *Melaleuca quinquenervia.* At the time of the survey ponding of water 300 mm deep was present. *Eleocarpus obovatus* is co-dominant with an understorey of *Hypolepis muelleri.*

At site 6 the deep sands of the Quaternary Alluvium extend along the Ourimbah Creek Valley but are absent from adjacent gullies. *S. paniculatum* appears to be confined only to the main Ourimbah Creek where these sands occur and appears to be eliminated from the side gullies where the Terrigal Formation Shales outcrop (viz., Harden 1986, Payne 1987). Vegetation present along the Ourimbah Creek may be described as gallery rainforest dominated by *Cryptocarya glaucescens* and *Acmena smithii* which Floyd (1985) has described as belonging to the *Acmena-Doryphora* alliance.

Annual average rainfall for North Entrance is 1266 mm (at North Head) and at Ourimbah about 1300 mm.

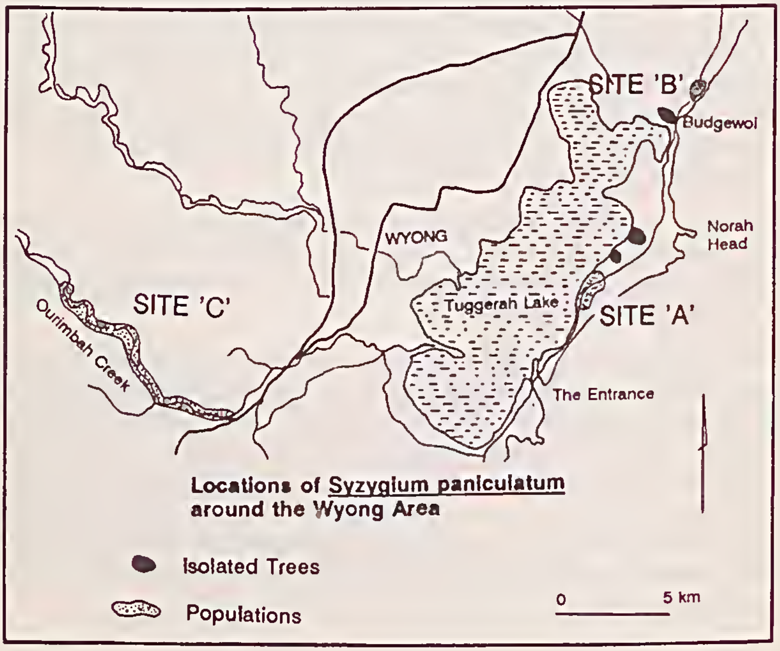

Figure 1. Location of populations of *Syzygium paniculatum.*

Ecology

It appears *Syzygium paniculatum* is able to tolerate both wet and dry conditions on sands. At Site B the presence of an understorey of *Hypolepis muelleri* and the presence of *Melaleuca quinquenervia* adjacent suggests permanent moisture. A flooding regime at Site C further suggests inundation is tolerated. Ourimbah Creek Valley is flooded several times each year.

Fire appears to be a regenerative mechanism. At Site A many trees have coppiced stems with the original main stem being burnt out. This response appears to be similar to *Acmena smithii* and *Backhousia myrtifolia*, though the effect of frequent fires is not known.

No information is available on the regenerative potential from seed. The population in the Ourimbah Creek Valley was revealed because the White-headed Pigeons (*Columba leucomela*) were feeding on the fruit. However there is little evidence of regenerating seedlings but cattle graze amongst the population. A heavy fruit was set in March 1990.

Conservation potential

Planning for the inclusion of the population at Site A into the Wyrrabalong National Park is underway. A decision by National Parks and Wildlife Service and the New South Wales Department of Lands is pending.

Site B has potential to be conserved within the Munmorah State Recreation Area for the population lies alongside the southern boundary. Site C has some potential for conservation as the population lies on both rural private property and Crown land.

Conclusions

Syzygium paniculatum in the Wyong area appears to be confined to Quaternary sands in rainforest but absent from the Terrigal Formation shales where gully rainforests occur. It appears to tolerate variable habitat conditions and resprouts after fire. Adequate protection of populations is needed if long-term conservation is to be assured.

Acknowledgments

I would like to thank my two colleagues, Andrew Sourry and Peter Clifford for helping with field work. Many thanks to Peter Wilson for verifying my findings and Doug Benson for editing the manuscript.

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Manuscript received 23 October 1990
Manuscript accepted 7 March 1991

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SHORT COMMUNICATION

Ecology of Sydney Plants Project

Conventional floras and handbooks provide descriptions for identifying species, but give relatively little ecological and biological data. Yet such data is becoming increasingly relevant to researchers in many fields and to natural area managers, who have the task of trying to predict the ecological consequences of management regimes, such as fire frequency, on native vegetation. Such data are also important for environmental impact assessment and for predicting the effects of changes in drainage, water movement, wind exposure or nutrient conditions on plant species and communities.

The Sydney region is interpreted broadly, being defined here as by Beadle, Evans and Carolin in the *Flora of the Sydney Region*. It thus covers the area bounded by Newcastle, Singleton, Rylstone, Taralga and Nowra. Information provided will be largely complementary to taxonomic descriptions, and will include growth form, flowering and fruiting times, longevity and maturity periods, pollination and seed dispersal data, distribution, habitat and plant community, and responses to fire and disturbance.

The project will be based at the New South Wales National Herbarium and will involve gathering material from published and unpublished sources as well as herbarium records and field observations. Much of the information is difficult to obtain because it is either scattered through a wide range of publications, both scientific and general, or simply not available in written form, but held in the capacious memories of field and herbarium botanists. Often indeed no-one has noted, for example, whether a species resprouts after fire, or how it is dispersed. Direct field observations will therefore supplement the review of literature. The emphasis in the first instance will be on providing information that is available, and the project will inevitably demonstrate a lack of knowledge about many plant species. Collaboration with other ecologists and botanists as well as with other interested people will be sought.

The types of information to be gathered are indicated below:

Growth form
Longevity
Growing season
Vegetative spread
Time to first flowering
Pollen vector
Time to first fruiting
Fruiting time
Time of seed dispersal
Seed production
Appendages on dispersal unit
Seed size
Seed weight
Seed longevity
Dormancy mechanism
Dispersal mechanism
Germination requirements
Interaction with other organisms
Distribution
Locations
Botanical subregions
Habitat
Typical abundance
Vegetation
Substrate
Soil nutrient
Soil drainage
Moisture supply
Soil salinity
Soil pH range
Shade
Exposure
Altitude
Annual rainfall
Response to fire
Seed bank
Conservation

We plan to proceed by the following steps:

- Literature review and preparation of draft listings that will be made available progressively to ecologists and botanists who can assist by filling gaps in the information. A database will be developed to record both data and the source from which each item has been obtained.

- Publication in *Cunninghamia* of the work in about ten parts, each covering about 250 species. If feasible, parts will be produced annually. Such publication will again assist in obtaining information from other sources, as well as making the data accessible as it becomes available.

Part 1 Ferns, Fern-allies, Cycads and Conifers

Part 2 Acanthaceae to Brassicaceae

Part 3 Cabombaceae to Eupomatiaceae

Part 4 Fabaceae

Part 5 Flacourtiaceae to Myrsinaceae

Part 6 Myrtaceae

Part 7 Nyctaginaceae to Rubiaceae

Part 8 Rutaceae to Zygophyllaceae

Parts 9 & 10 Monocotyledons

- Eventually a comprehensive publication covering all groups is planned. This will update the information given in the earlier publication of sections of the work.

Manuscript received 3 June 1991
Manuscript accepted 3 July 1991

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SHORT COMMUNICATION

Flowering times of plants found in Oxley Park, Tamworth. An addendum

Macrozamia

Following publication of my paper 'Flowering times of plants found in Oxley Park, Tamworth' (*Cunninghamia* 2(2): 197–216), Dr Lawrie Johnson (National Herbarium of NSW) informed me that the *Macrozamia* referred to in the table and the discussion was incorrectly identified. The species at Oxley Park is *Macrozamia stenomera* L. Johnson not *Macrozamia diplomera. M. stenomera* is listed by Briggs and Leigh (1988) as a rare species with a range of less than 100 km. It is conserved in Mount Kaputar National Park but no information is available on the adequacy of reservation. The species is recorded from as far north as Bingara and is now known from three collections from the Tamworth district (L. Johnson pers. comm.).

Aphanes

One other native species, *Aphanes australiana* (Rothm.) Rothm., a member of the family Rosaceae has been found in the Park since publication. This species flowers in September and October. Although first noted late in 1990, the plant is locally common and was probably overlooked in the past because of its small size.

Reference

Briggs, J.D. & Leigh, J.H. (1988) *Rare or threatened Australian plants*, Special Publication No. 14 (Australian National Parks & Wildlife Service: Canberra).

Manuscript received 19 February 1991
Manuscript accepted 3 July 1991

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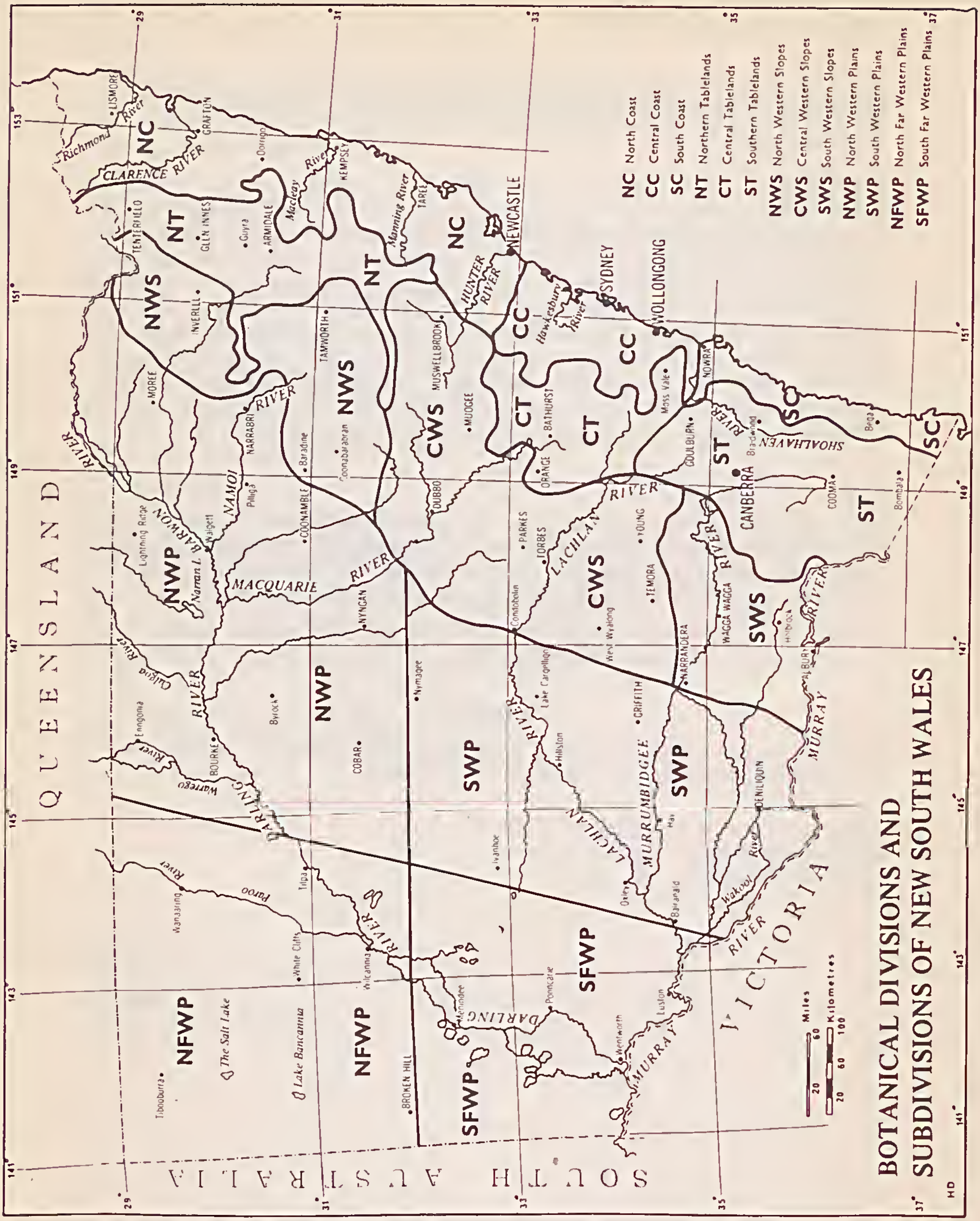

For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R. H. (1961). Introduction. *Contr. New South Wales Natl. Herb. Fl. New South Wales* Nos 1–18, pp. 1–15.

INFORMATION FOR AUTHORS

Cunninghamia is published annually in July. Papers dealing with all aspects of plant ecology, in particular vegetation mapping and plant community dynamics are welcome to be considered for publication. Papers dealing primarily with New South Wales or with comparitive data from New South Wales and neighbouring states will be given preference. Brief papers may be published as Short Communications (see previous issues for format).

The deadline for the submission of papers is **1 October** for publication in the following year. Authors are expected to have had their papers peer-reviewed before submission. All papers will be refereed. Two copies of the manuscript should be submitted along with originals of photographs and clear photocopies of all other figures. The full postal address (plus telephone and fax numbers) of the author who will check the proofs and receive correspondence should be included. Once a paper has been accepted for publication the author should provide the paper on a computer disk along with the final artwork for figures etc. The disk should be in IBM compatible (MS-DOS) or Macintosh format and clearly labelled with the word processing program used and the file name(s).

Organisation of the paper The title should be explicit and descriptive of the content; a short running title and an abstract (except for Short Communications) should be included. Check most recent issue for format. It would be helpful if authors could indicate in the margin the relative importance of the headings.

General formatting requirements • Text should be flush left. This applies also for abstracts, headings, keys and reference lists. Headings should be in upper and lower case, and not underlined. • Use only a single space after *all* punctuation marks including fullstops. • Insert a space between a numeral and unit of measurement, e.g. 3 km, but no space between initials, e.g. L.A.R. Haegi, or between a hyphen and associated numerals, e.g. 5.2-6 mm. • Do not use the spacebar to indent or tabulate. •Underline, in preference to italics, and use single quote marks before double. • Species lists should be in one column, flush left.

Abbreviations, units etc. SI units (metre, kilogram etc.) are to be used. Statistics and measurements should always be given in figures, e.g. 10 mm, except where the number begins the sentence. *The Macquarie Dictionary*, latest edition, and the *Style Manual for Authors, Editors and Printers*, 4th edn, AGPS, 1988, should be consulted for spelling, abbreviations and other conventions.

References References in the text should be made by giving the author's name with the year of publication in parentheses. For reference list at end of paper see papers in this issue for style. If several papers by the same author and from the same year are cited, a, b, c, should be put after the year of publication. Titles of journals should be given in full or abbreviated in accordance with the latest (4th) edition of the *World List of Scientific Periodicals.*

Illustrations/maps/photos • In general figures should be drawn one and a half times the final printed size. Check that line thickness and evenness, and labelling size are suitable for the final reproduction size and that maps show their context clearly (by lat/longs or an inset map) and that relevant place names in the text (but not for cited specimens) are shown. • Submit line drawings as bromide (Repromaster) copies with the final manuscript. • Photos should be unmounted, good-quality gloss prints. Do not label photos. • Labelling that is part of an illustration, e.g. place names on a map, should be added in Helvetica font by the person preparing the illustration. • Bar scales for maps and photographs are preferred to numerical scales. • Bear in mind the shape of the final printed page and that the maximum final size of the illustration is 205 mm high x 125 mm wide, but preferably less to leave space for a caption on the same page. • Authors wishing to submit large or complex maps should discuss cartography with the editors before final preparation.

Captions Use lower case letters for the parts of a figure e.g. **Figure 1.** The plant communities of Bents Basin S.R.A. showing **a**, Forest Hill Creek section and **b**, Little Mountain section.

Tables should preferably be portrait rather than landscape shape i.e. taller rather than wider. They should be typed as separate files. Column headings should be brief with units of measurement in parentheses. Each table must be referred to in the text and its approximate position should be indicated in the margin of the manuscript. Please remember tables need to fit into the journal page size.

More detailed instructions are available on request from the editors.

ANA BRANCH – MILDURA

1: 250 000 VEGETATION SERIES

LIFE FORM	FOLIAGE COVER CLASSES		
	30–70%	10–30%	<10%
Medium trees 10–30 m	M3	M2	
Tall shrubs >2 m	S3	S2	
Low shrubs <2 m		Z2	Z1
Tussock grass & gramminoids	G3		
Other herbaceous plants		F2	

UPPER STRATUM SYMBOLS AND CODES		
Code letter	Life form	Genus, family or group
c	Tree/shrub	*Casuarina*
e	Tree/shrub	*Eucalyptus*
k	Tree/shrub	Chenopodiaceae
g	Herb	Graminoids
k	Herb	Chenopodiaceae
y	Herb	Other grasses

LOWER STRATUM CODE	
Code letter	Life form of lower stratum
S	Tall shrub >2 m
Z	Low shrub <2 m
H	Hummock Grass *Triodia irritans*
F	Other herbaceous plants including small chenopods

MAP UNIT DESCRIPTIONS					
Pattern	No.	Code	Structure	Main species	Dominant plant community
▨	1	eM3F	Open-forest	*Eucalyptus camaldulensis*	Riverine Forest
	2	eM2S	Low open-woodland	*Eucalyptus largiflorens* *Atriplex nummularia*	Black Box Woodland
∘	3	eS2H	Tall shrubland	*Eucalyptus socialis* *E. dumosa*	Dune Mallee
	4	cS2Z	Tall shrubland	*Casuarina pauper* *Alectryon oleifolius* subsp. *canescens*	Arid Shrubland
	5	eS2H/ cS2Z	Tall shrubland	Mosaic of 3 with 4	Arid Shrubland
	6	cS2Z/ eS2H	Tall shrubland	Mosaic of 4 with 3	Arid Shrubland
	7	cS2Z/ eS2H/ kZ2F	Tall shrubland	Mosaic of 4, 3 & 8	Arid Shrubland
☰	8	kZ2F	Low shrubland	*Maireana pyramidata* *Rhagodia spinescens*	Black Bluebush
	9	kZ2F	Low shrubland	*Maireana sedifolia* *Erodium* spp.	Bluebush
	10	kZ2F	Low shrubland	*Maireana pyramidata* *Atriplex* spp.	Lunette Shrubland
	11	kZ1F	Low open-shrubland	*Atriplex vesicaria* *Sclerostegia tenuis*	Bladder Saltbush
	12	kZ1F	Low open-shrubland	*Sclerostegia tenuis* *Atriplex* spp.	Pigface-Samphire
v	13	yG3F	Grassland	*Eragrostis australasica*	Canegrass Swamp
	14	gG3F	Sedgeland	*Eleocharis pallens*	Sedge Swamp
	15	kF2F	Open-herbland	*Disphyma clavellatum* *Sclerostegia tenuis*	Saltpan, Lakebed
Plant communities too small to be shown as separate map units.		eS2H	Tall shrubland	*Eucalyptus oleosa*	Sand Plain Mallee
		eS2H	Tall shrubland	*Eucalyptus gracilis*	Swale Mallee
		pM2S	Open-woodland	*Callitris glaucophylla*	Mixed Woodland
		wS3F	Tall shrubland	*Acacia victoriae*	Acacia Shrubland
		xS4F	Closed shrubland	*Muehlenbeckia cunninghamii*	Lignum Swamp
		kS3F	Tall shrubland	*Atriplex nummularia*	Old Man Saltbush

Map units show original vegetation cover before European settlement, as interpreted from aerial photography and field survey. Present vegetation has been affected by widespread grazing and localised clearing.

KEY TO ADJOINING MAPS

OLARY SI54-2	MENINDEE SI54-3	MANARA SI54-4
CHOWILLA SI54-6	ANA BRANCH SI54-7	POONCARIE SI54-8
RENMARK SI54-10	MILDURA SI54-11	BALRANALD SI54-12
PINNAROO SI54-14	OUYEN SI54-15	SWAN HILL SI-54-16

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Natural Vegetation

of the

ANA BRANCH – MILDURA
New South Wales

1:250 000 Map Sheet

Marilyn D. Fox

Descriptions of the plant communities are given in Cunninghamia 2(3) 1991

Compiled and prepared at the
National Herbarium of New South Wales
Royal Botanic Gardens Sydney

Understanding the ecology of our native plants

PLANT COMMUNITIES OF THE
ANA BRANCH – MILDURA
1:250 000 MAP SHEET

Major plant communities

1. Riverine Forest

Map units: 1 (2)
Code: eM3F
Structural formation: Open-forest
Height: 25–40 m
Cover: 30–70%
Dominant species: *Eucalyptus camaldulensis* on levees: *E. largiflorens* on flats and along smaller streams.
Understorey species: *Acacia stenophylla, Chenopodium nitrariaceum, Melaleuca lanceolata.*
Ground layer: Mix of herbaceous species, many exotics
Species richness: (0.1 ha) 23.4 ± 4.1 (n=5)
Landform: River levees and flats between braided streams.
Habitat (photopattern): Often concentric linear photopatterns with oxbows
Soil: Heavy grey alluvium
Degradation/regeneration: Subject to frequent and prolonged flooding, major regeneration occurs as floods subside leading to 'wheatfield' regeneration of extremely dense seedling growth which gradually thin out as plants grow. Very fine stands of Riverine Forest occur along the upper reaches of the Anabranch and along the Murray River. Elsewhere they usually form a narrow band following the major streams.

2. Black Box Woodland

Map units: 2 (11, 12, 15)
Code: eM2S
Structural formation: Low open-woodland
Height:10–20 m
Cover: 10–30% (Basal area 0.5 m^2ha^{-1})
Dominant species: *Eucalyptus largiflorens*
Understorey species: *Atriplex nummularia, Chenopodium nitrariaceum.*
Ground layer: *Osteocarpum acropterum* var. *deminutum, Boerhavia diffusa, Chamaesyce drummondii, Scleroblitum atriplicinum*
Species richness: (0.1 ha) 36.6 ± 3.0 (n=7)
Landform: Floodplains beyond major rivers and dry lake margins
Habitat (photopattern): Along creek lines and less dense than Riverine Forest
Soil: Heavy grey clay
Degradation/regeneration: Subject to periodic inundation, major regeneration occurs as floods subside. Most stands contain trees of similar size (age) and may represent past establishment patterns. The Black Box Woodlands are prime grazing country and the understorey is affected by this land use. In particular much of the previously extensive *Atriplex nummularia* stands that formed a shrub layer under and between the Black Box trees have now been lost.

3. Dune Mallee

Map units: 3 (5, 6, 7)
Code: eS2H
Structural formation: Tall shrubland
Height: 2–10 m (function of time since fire)
Cover: 10–30% (Basal area $5m^2$ ha^{-1})
Dominant species: *Eucalyptus socialis, E. costata, E. dumosa*
Understorey species: *Triodia irritans, Beyeria opaca, Podolepis capillaris, Chenopodium curvispicatum, Stipa nitida, Enchylaena tomentosa*
Species richness: (0.1 ha) 25.4 ± 0.8 (n= 5)
Landform: Longitudinal east-west dunes up to 10 m in height
Habitat (photopattern): Forms prominent small-grained photopattern
Soil: Calcareous red sand overlying grey clay
Degradation/regeneration: The dunes may become active with a wind-blown sandy surface if highly disturbed. Whereas the mallee eucalypts can resprout from lignotubers, *Triodia* is killed and new plants germinate soon after fire. Seedling eucalypts were rarely noted. Some areas of mallee have been cleared in the past.

4. Arid Shrubland, Belah-Rosewood

Map units: 4 (5, 6, 7)
Code: cS2Z
Structural formation: Tall shrubland
Height: 8–12 m
Cover:10–30% (Basal area 2.5 m^2ha^{-1})
Dominant species: *Casuarina pauper, Alectryon oleifolius* subsp. *canescens.*
Understorey species: *Maireana pyramidata, Olearia pimeleoides, Enchylaena tomentosa, Sclerolaena* spp., *Aristida contorta.*
Species richness: (0.1 ha) 39.7 ± 4.6 (n= 6)
Landform: Raised areas of highly calcareous heavy soils with calcrete fragments
Habitat (photopattern): No dunes apparent and uniform mottled photopattern
Soil: Fine red sandy loam with calcrete nodules
Degradation/regeneration: Preferentially cleared because of its slightly better soil and because the dominant species do not resprout as readily as mallee does.The dominant species form clumps and this creates a mosaic pattern. *Alectryon* flowers irregularly and no seedlings were observed. Root suckers develop around parent plants but are highly palatable to sheep and rabbits and are kept grazed down.

5. Arid Shrubland (mosaic of map unit 3 with 4)

Code: eS2H/cS2Z
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Dune Mallee (3) with Belah-Rosewood (4)
Habitat (photopattern): At least 70% of the area is dunefield but widely spaced with 4 in swales

6. Arid Shrubland (mosaic of map unit 4 with 3)

Code: cS2Z/eS2H
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3)
Habitat (photopattern): Finer grained photopattern than 5, predominately 4, may have some dunes with mallee but too small to map

7. Arid Shrubland (mosaic of map units 4, 3 & 8)

Code: cS2Z/eS2H/kZ2F
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3) and Black Bluebush (8)
Habitat (photopattern): Quite irregular, more patchy than 4 and with occasional open patches (8), each component too small to map separately

8. Black Bluebush

Map units: 8 (9, 10)
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, Rhagodia spinescens*
Understorey species: *Sclerolaena* spp., *Osteocarpum acropterum* var. *deminutum, Atriplex* spp.
Species richness: 35.4 ± 2.7 (n= 9)
Landform: Clay plain
Habitat (photopattern): Some scattered clumps of 4
Soil: Calcareous red loamy sand, red-brown loam, consistently with calcretions in top 40 cm
Degradation/regeneration: Under grazing no regeneration occurs. Sheep browse these perennial shrubs but goats and rabbits are more damaging, often ring-barking the main stems and excavating and eating the roots. Degraded areas may be invaded by *Nitraria billardieri.*

9. Bluebush, Pearl Bluebush

Map unit: 9
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana sedifolia*
Understorey species: *Erodium* spp., *Tetragonia tetragonioides, Sclerolaena* spp.
Species richness: (0.1 ha) 24.7 ± 1.1 (n= 5)
Habitat (photopattern): More open than 8, some clumps of 4
Landform: Typically upslope of Black Bluebush on clay plain
Soil: Red sandy loam with nodules of calcrete in the top horizon
Degradation/regeneration: As for Black Bluebush. This shrubland also occurs with a mallee overstorey in restricted areas west of the Anabranch.

10. Lunette Shrubland

Map unit: 10
Code: kZ2F
Structural formation: Low shrubland
Height: 0.8–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, M. appressa*
Understorey species: *Sclerolaena* spp., *Atriplex* spp.
Species richness: No estimate
Habitat (photopattern): Gypseous dunes associated with lakes, including lunettes
Landform: Gypseous dunes associated with lakes, including lunettes
Soil: Saline gypseous clay mantling sand core
Degradation/regeneration: These landforms can erode to create spectacular features such as the Walls of China at Lake Mungo. Such erosion usually follows periods of over-grazing and trampling. Few perennial plants persist on lunettes and no regeneration was observed.

11. Bladder Saltbush

Map units: 11 (12, 15)
Code: kZ2F
Structural formation: Low shrubland
Height: 0.2–1 m
Cover: 10–30 %
Dominant species: *Atriplex vesicaria*
Understorey species: *Sclerostegia tenuis, Pachycornia triandra, Osteocarpum acropterum* var. *deminutum, Disphyma clavellatum*
Species Richness: (0.1 ha) 18.1 ± 2.1 (n= 5)
Landform: Lower Alluvium, alluvial plains
Habitat (photopattern): Fine-grained, often with pronounced curvilinear patterns from paleochannels
Soil: Grey-brown clay loam, surface cracked
Degradation/regeneration: Often heavily grazed, affecting the shrub vitality and cover. No seedling regeneration was observed in the study area throughout the survey period. Degraded areas may be invaded by *Nitraria billardieri.*

12. Pigface – Samphire

Map units: 12 (11, 15)
Code: kZ1F
Structural formation: Low open-shrubland.
Height: 0.1–0.4 m
Cover: <10%
Dominant species: *Disphyma clavellatum, Sclerostegia tenuis* (may have overstorey of *E. largiflorens*)
Understorey species: *Annual Atriplex, Sclerolaena* spp.
Species richness: No estimate
Landform: Saline flats
Habitat (photopattern): Associated with 15
Soil: Pale cream-grey cracking clay
Degradation/regeneration: It is generally considered that *Disphyma clavellatum* is now much reduced in abundance since settlement, due to grazing and trampling (Cunningham et al. 1981). This community may grade into saltpan.

13. Canegrass Swamp

Map units: 13 (11, 15)
Code: yG3F
Structural formation: Grassland
Height: 1–3 m
Cover: 30–70 %
Dominant species: *Eragrostis australasica, Muehlenbeckia cunninghamii*
Understorey species: Usually absent
Species richness: No estimate
Landform: Depressions in clay plain
Habitat (photopattern): With scattered trees of *Eucalyptus largiflorens*
Soil: Grey cracking clay
Degradation/regeneration: Subject to intermittent flooding where water remains several months. May have scattered trees of *Eucalyptus largiflorens.* Important wildlife habitat particularly for nesting waterbirds, although it can also harbour feral pigs.

14. Sedge Swamp

Map unit: 14
Code: gG3F.
Structural formation: Sedgeland
Height: 0–0.5 m
Cover: 30–70 %
Dominant species: *Eleocharis pallens*
Understorey species: Usually absent
Species richness: No estimate
Landform: Flats or depressions within Riverine Forest, margins of swamps, claypans and lakebeds
Habitat (photopattern): Flats within Riverine Forest
Soil: Variety of clay soil.
Degradation/regeneration: Responds quickly to rain and grows throughout the year if water is available. Only is grazed by stock if other more palatable species are unavailable.

15. Saltpan, Lakebed

Map units: 15, Lake
Code: kF2F
Structural formation: Open herbland
Height: 0–0.2 m
Cover: 10–30 %
Dominant species: *Sclerostegia tenuis, Muehlenbeckia cunninghamii, M. horrida* (edges)
Understorey species: *Atriplex leptocarpa, A. pseudocampanulata, Disphyma clavellatum*
Species richness: No estimate
Landform: Saltpan or clay flat often areas of groundwater discharge, some lakebeds
Habitat (photopattern): Saltpan or clay flat
Soil: Highly saline gypseous flats, fine-grained clay, large desiccation cracks
Degradation/regeneration: Many of the larger lakes are now cultivated and in such cases, all native vegetation has been destroyed..

Plant communities too small to be shown as separate map units

Sand Plain Mallee

Map units: 3, 5, 6, 7
Code: eS2H
Structural formation: Tall shrubland
Height: 6–10 m
Cover:10–30 %
Dominant species: *Eucalyptus oleosa, E. socialis, E. gracilis*
Understorey species: *Chenopodium curvispicatum, Ptilotus exaltatus* var. *exaltatus, Olearia muelleri*
Species richness: (0.1 ha) 23.7 ± 1.1 (n= 5)
Landform: Sand plain, sand ridges
Soil: Calcareous sandy red earth, red duplex soil
Degradation/regeneration: More easily cleared than Dune Mallee because of flatter topography and heavier soil. No eucalypt seedling regeneration noted.

Swale Mallee

Map units: 3, 5, 6, 7
Code: S2H
Structural formation: Tall shrubland
Height: 2–10 m
Cover: 10–30 %
Dominant species: *Eucalyptus gracilis, E. dumosa*
Understorey species: *Enchylaena tomentosa, Dissocarpus paradoxus, Senna artemisioides, Sclerolaena* spp.
Species richness: (0.1 ha) 34.2 ± 1.4 (= 5)
Landform: Swales between sand dunes and deflated sand plains
Soil: Calcareous red sand
Degradation/regeneration: More subject to clearing than the dune mallee. Often the sites for watering points and ground tanks and therefore prone to trampling and over-grazing.

Mixed Woodland, Callitris Woodland

Map units: 4, 11
Code: pM2S
Structural formation: Open woodland
Height: 8–12 m
Cover: 10–30 %
Dominant species: *Callitris glaucophylla, Hakea leucoptera, Hakea tephrosperma, Myoporum platycarpum*
Understorey species: *Maireana pyramidata*
Species richness: no estimate
Landform: Sandy rises adjacent to riverine flats, source-bordering dunes
Soil: Deep loose sandy soil. On sandhills along the Murray and lowermost part of the Darling, Murray Pine, *Callitris preissii* subsp. *murrayensis* occurs and also much *C. preissii–C. glaucophylla* hybridisation (L.A.S. Johnson pers. comm.)
Degradation/regeneration: often cleared for valuable timber trees and only identifiable by the landform and scattered remnant trees. Further east of the mapped area this landform is often cultivated for wheat and other cereal crops. Similar woodland may be found on sandy rises on the western sides of lakes as well, for example west of Popiltah Lake. Such stands are always of small area and cannot be mapped at the scales employed here.

Acacia Shrubland

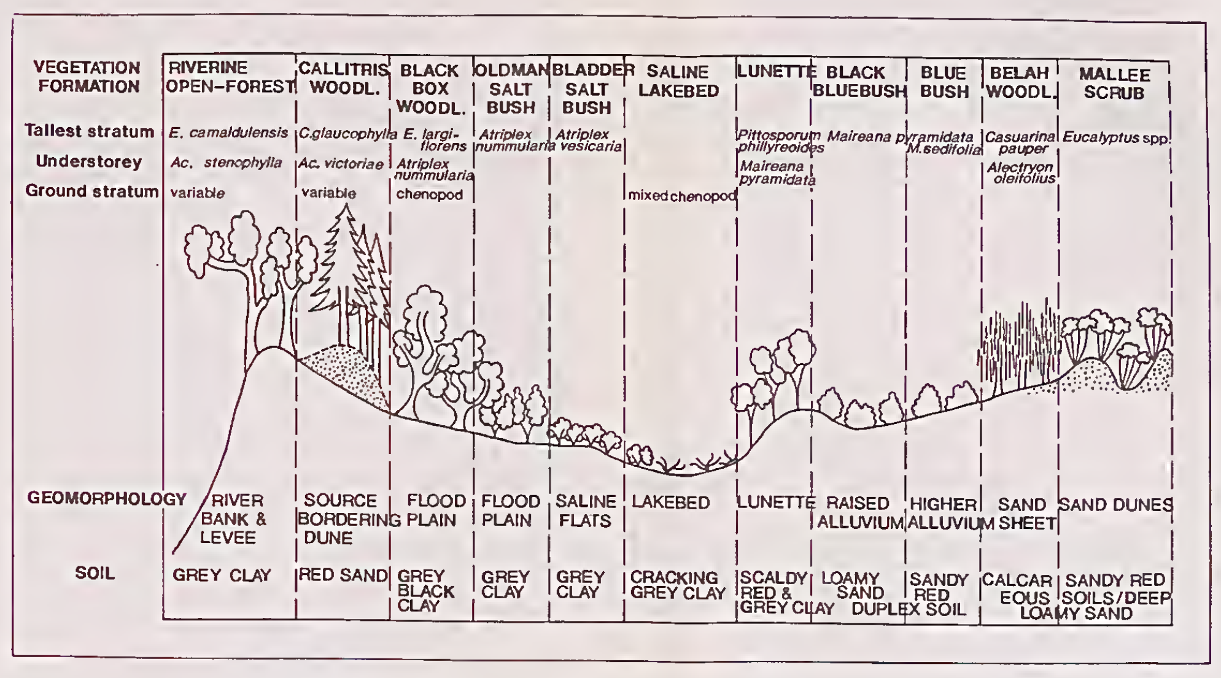
Map units: 1, 2, 4
Code: wS3F
Structural formation: Tall shrubland
Height: 2–6 m
Cover: 30–70%
Dominant species: *Acacia victoriae, Dodonaea, Acacia oswaldii*
Understorey species: *Sclerolaena* spp., *Maireana* spp.
Species richness: No estimate
Landform: Sandy rises such as source-bordering dunes which extend along rivers and major streams, creek beds and banks in a variety of landforms
Soil: Red sandy soil
Degradation/regeneration: Remnant trees of *Myoporum platycarpum, Hakea leucoptera, Hakea tephrosperma, Callitris glaucophylla* and *Callitris preissii* subsp. *murrayensis* may occur. This may represent highly disturbed areas that previously supported *Callitris* woodland. The dominant species may be mainly the 'woody weeds' which are invasive, colonising, native species.

Lignum Swamp

Map units: 2, 12, 14
Code: xS4F
Structural formation: Closed scrub
Height: 2–8 m
Cover: 70–100 %
Dominant species: *Muehlenbeckia cunninghamii* (*Eucalyptus camaldulensis, E. largiflorens* around edges)
Understorey species: Usually absent
Species richness: No estimate
Landform: Depressions with impounded water
Soil: Heavy clay
Degradation/regeneration: Very important wildlife habitat particularly for nesting waterbirds. Regenerates readily under favourable flood conditions.

Old Man Saltbush

Map units: 2
Code: kS3F
Structural formation: Tall shrubland
Height: 1–2 m
Cover: 30–70 %
Dominant species: *Atriplex nummularia, Rhagodia spinescens,* (*Eucalyptus largiflorens*)
Understorey species: *Atriplex* spp., *Sclerolaena* spp.
Species richness: No estimate
Landform: River flat
Soil: Clay soils
Degradation/regeneration: Grades into *Maireana pyramidata* shrubland away from the river. These deeply rooted shrubs can withstand severe drought and also tolerate flooding, but can be decimated by heavy continuous grazing. Only small relict stands remain of what were more extensive stands (Cunningham et al. 1981).



Idealized vegetation continuum from river to sand dunes showing relative topographic arrangement of major vegetation types.

CUNNINGHAMIA 2(3): 343-501 • 1991

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ISSN 0727–9620